DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT OF THE

FOREST PRODUCTS RESEARCH BOARD

With the Report of the Director of Forest Products Research

FOR THE PERIOD ENDED 30th SEPTEMBER, 1928

LONDON: PUBLISHED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE, 1929

47-74-0-28

FOREST PRODUCTS RESEARCH BOARD

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REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR THE PERIOD ENDED 30TH SEPTEMBER, 1928

To the Lords of the Committee of the Privy Council for Scientific and Industrial Research

MAY IT PLEASE YOUR LORDSHIPS,

THE opening of the Forest Products Research Laboratory at Princes Risborough, Buckinghamshire, in June, 1927, marked the completion of what has been the main constructive period in the work of the Forest Products Research Board. The staff have now been in occupation of the new premises for fully a year and have brought them into full working order. The present is, therefore, an opportune time to present to Your Lordships, as our first serial report, a review of the developments which have taken place since the Board first began work at the end of 1921. In presenting this report we have taken the opportunity of restating our policy and the reasons which have determined it, and of setting out the programme of work which we are attacking.

THE NEED FOR RESEARCH

2. The wholesale felling of British woodlands during the war, the rise in prices, and the threat of a coming world shortage of "softwood" building timber, all combined to attract attention to the question of timber supplies as an urgent post-war problem.

The necessity for the conservation of existing timber resources and the creation of new ones, especially in a country so dependent on its imports of timber as Great Britain, resulted in the creation of the Forestry Commission.

"Save timber and you save a tree." The realisation of the fact that existing supplies could be conserved not only by proper management of the standing crop, but also by the reduction of waste in the utilisation of timber, led to the establishment of the Forest Products Research Board and Laboratory.

3. The need of the British user for organised research was made increasingly evident by the conditions existing in the great timber producing countries. In these countries, where timber production is a primary industry, there was already on foot an intense campaign to reduce waste. The impetus thus given to the search for better technique had resulted in the establishment of such national laboratories as the United States Forest Products Laboratory at Madison, the Indian Government Forest Research Institute at Dehra Dun, and the Canadian Government Laboratories at Montreal (since removed to Ottawa) and Vancouver. In Canada and the United States of America added impetus to research was given by internal competition among the big saw-milling firms. These firms sought for new knowledge both to make their own operations cheaper and to attract repeat orders by enabling their customers to get the best results from the timber supplied. This competition led also to a search for foreign markets—a search conducted, therefore, by firms already advanced in the technique of preparing their goods for market and continually aided by expert advice from their national research institutions.

4. American competition for British markets in timber-manufactures illustrates an outstanding difference between a country which is primarily a producer and one, such as Great Britain, which is primarily a user. In the timber-producing country

the saw miller is the controlling factor. To sell his products he finds it to his interest to broadcast information on the best technique for dealing with them. This tends to a conscious movement for co-operation between the local producer and the local user, aiming at better use of scientific and technical knowledge of the properties and qualities of the local timbers. In the timber-using country, on the other hand, there is no compelling evidence of a community of interest among timber users in the pursuit of increased knowledge of the properties and uses of timber which are already, or may in future become, available in the markets of the country. The wood-using firm, as a rule, has therefore only its own resources to look to for advances in technique. In these circumstances foreign competition in timber-manufactures has, during the last twenty years, increasingly threatened the once pre-eminent position of the British manufacturer in the home market. The only remedy is to be found in the means which Germany, in particular, employed to counter the advantages which this country enjoyed after the industrial revolution of last century : technical study and research.

5. The British manufacturer, therefore, needs experts who shall (1) collect and distribute all available knowledge, (2) seek new knowledge, and (3) help industry to apply the knowledge. The primary motive in these needs is the reduction of waste, important alike to the manufacturer of timber products and to his customer—the public.

6. A further need for research in forest products arises from demands for information on the part of the grower of timber. The State, acting through the Forestry Commission, is now in course of producing part of this country's timber requirements. The grower, whether the State or the private owner, wishes to know the characteristics of the timbers of the different species as grown in this country. Especially for those species which have been recently introduced does he wish to know their potential uses and the comparative value of two or more species for any one purpose. Moreover, the requisite qualities of the timber in strength, fineness of grain or freedom from knots, and so forth, will vary in degree and importance according to the purpose for which it is to be used, and the grower will need information about these requirements. The rate of growth of the tree, as measured by the width of the annual ring, has an effect on the strength of the timber ; and the grower should know what rate of growth produces the strongest timber. He should know what size of log is most suitable for producing a particular class of material with the minimum of waste. Knowledge of these matters should govern the choice of species for planting and will enable the grower to decide upon the appropriate silvicultural treatment of his woods. Three illustrations of work directed to such ends are the investigations on the respective merits of different species of conifers for use as pit-props, those on the quality of Corsican pine timber, and those on the conversion, quality and uses of undersized oak, which are described in detail in the Director's report.

The Origin of the Laboratory

7. At the end of the war it was widely recognised that a national policy was needed for promoting economy in the utilization of the timber supplies of this country and for developing the available timber resources of other parts of the Empire. A similar need, varying in point of detail with local conditions, was evident not only for the tropical forest regions in the Colonies and Protectorates but in the self-governing Dominions. It was this need which led in 1920 to the first meeting, in London, of the British Empire Forestry Conference. At this meeting the Conference made recommendations to the various Governments in the Empire for the organization

of that research work which was considered essential to the progress of forestry. These recommendations dealt with both the growing of forest crops and their utilization. For Great Britain they contemplated on the one hand a research institute which should deal with the problems of growing, and on the other a research organization, which should include a central institute, to deal with the utilization of forest products.

8. These recommendations were duly considered by the Government. The arrangements necessary to give effect to the first did not directly concern the Department of Scientific and Industrial Research ; but for the utilization of forest products your Lordships were authorised to set up the necessary organization, to make the financial provision required for its work, and to appoint a Forest Products Research Board for its guidance.

9. The experience of research on the utilization of forest products gained in the great timber-producing countries such as Canada, India, and United States of America could not be accepted uncritically as a guide to procedure in Great Britain. The task of the new organization was to study the very different problem of forest products research in a country which is a large importer and user, but at present an insignificant producer of timber. It had to determine how far, and on what lines, a government organization in this country could usefully intervene in the conduct of research and in the application of the results by industry. It reached conclusions which find their counterpart in the work the Department is carrying out in connexion with even more important natural resources, food and fuel.

10. The Forest Products Research Board, which began work at the end of 1921, found it possible two and a half years later to submit a complete scheme of organization, and to make out a case—which received Government approval—for the heavy expense of providing in this country a fully equipped Forest Products Research Laboratory. Three years later the Laboratory was completed on a site of 25 acres selected, with a particularly suitable location, at Princes Risborough.

11. In the meantime temporary accommodation had been secured in Air Ministry premises at Farnborough, where it was possible to bring into being a nucleus organization and to collect and train a suitable staff. In October, 1925, your Lordships were able to secure the services of the present Director of Research, Mr. R. S. Pearson, C.I.E., who had just retired after 28 years in the Indian Forest Service, for 16 of which he was in charge of the Economic Branch of the Forest Research Institute, Dehra Dun. Since that date the work has proceeded under his direction and when the completed building at Princes Risborough was handed over by the Office of Works in 1927, the beginning made at Farnborough enabled your Lordships to transfer to the new station a staff and organization capable of bringing it into full use.

The Object of the Laboratory

12. As we have shown, the primary purpose of the Laboratory is to promote, in the national interest, the more economical use of timber by the timber-using industries of this country. In the specification of more economical sizes determined by knowledge of the strength factors of the various timbers and grades of timber, in the reduction of waste by better seasoning, and in the prevention of decay, there is ample scope for the application of scientific knowledge and method to the uses made of timbers already known and marketed in this country. The importance of the need for this work may be measured by the large sums spent annually on importing timber (£60,000,000). The application of its results by the using industries would be of direct benefit to

all users of timber and the community generally. For this primary purpose, the source of origin of the timber used is a subordinate consideration. To the timber-user of this country it is just as important to avoid waste of foreign-grown timber as of Empire-grown timber.

13. In the exercise of this primary function the Laboratory will be called upon both to furnish information on the adaptability for new purposes of timbers already on the market and to investigate the qualities and uses of new timbers. A wide range of facilities is required if the information to be obtained is to be full and to supply all the knowledge needed to relate practical uses with technical qualities. The Laboratory is equipped to supply such a range of facilities.

14. Experience has shown that, broadly speaking, a research falls into three stages : laboratory tests ; large-scale tests ; and tests on a commercial scale to prove the economic soundness of the results. Exact scientific research is necessary to determine basic principles. These must then be employed as a guide for investigation of the practical problems to be solved. The results must then be tested to see whether their industrial application falls within practical politics. Progress therefore depends on the close co-operation of science and practice, and the organization of the Laboratory is designed to achieve this end. It includes also the expert assistance necessary to help industry to apply the results.

15. For progress on sound and thrifty lines close touch must be maintained with all the interests concerned. Co-ordination of timber production and utilization is secured by the presence on the Board of the Chairman of the Forestry Commission and the Technical Commissioner of Forestry, by investigations undertaken in co-operation with the Commission, and by the collaboration of the Commission's Utilization Officer and the Laboratory's Section of Utilization. Liaison with research on the growing of forest crops is doubly secured. Not only is the Director of the Imperial Forestry Institute, Oxford—who is also Professor of Forestry at the University—a member of the Board, but the Laboratory's Section of Wood Technology is at present housed at the Imperial Forestry Institute and works on a common programme with the Institute's Wood Technologist. The Institute examines a problem from the point of view of the growing tree, the Laboratory from that of its timber. Close touch is maintained with other institutions, such as the Imperial College of Science and Technology and the Imperial Institute, interested in problems touching our own field of work. The Section of Mycology is housed at the Imperial College and works under the supervision of Professor Percy Groom, F.R.S., while Dr. J. W. Munro, of the same College, advises on research in Entomology. The Officer in Charge of Utilization is a member of the Advisory Committee on Timbers of the Imperial Institute, a technical committee consisting of men of science, architects, builders, timber merchants, and members of the timber-using industries. The function of this Committee is to promote the use of Empire timbers. Liaison is equally close with allied branches of research maintained by the Department, such as building and fuel. Finally, close touch with the timber trade and the wood-using industries is maintained through the frequent visits of their representatives to the Laboratory and through the field of work of the Utilization Section.

Organization of the Laboratory

16. The Sections of the Laboratory organization, with their main purposes, are described in the Director's Report.

17. Of these sections, those of Administration, Seasoning, Timber Mechanics, Wood Preservation, Wood Working, Entomology and Utilization are housed at Princes Risborough. As already explained, the Section of Wood Technology is housed at the Imperial Forestry Institute, Oxford, and the staff work on a joint programme with the Institute's Wood Technologist. The Section of Mycology is housed at the Imperial College, London, while in Chemistry there are two workers at Oxford and another at St. Andrew's University.

Reception by Lord President

18. Representatives of the timber-using industries and of the official organizations interested, both in this country and the Dominions and Colonies, attended a reception by the Lord President at the Laboratory on 31st July. Opportunities were afforded of inspecting the various laboratories and workshops, and examining the work in progress. The interest taken in the Laboratory by so large a body of visitors representative of all sections of timber users was of good augury for the usefulness of the work to industry.

PROGRAMME OF WORK

General

19. At the outset the main bulk of the Laboratory's work must be directed towards the establishment of first principles and the accumulation of exact data concerning the character of the various species of timber on the English market and of the processes best calculated to secure their most efficient use. For obvious practical reasons priority has been given to home-grown timbers, and the larger part of our programme has, therefore, so far been devoted to the general investigation of the anatomical structure, aptitude for and methods of seasoning, strength values, durability, working qualities and uses of these timbers. A few specialized tests have been undertaken in connexion with special uses, such as the determination of the strength and suitability of different species for use as pit-props. In all this work we have been most careful to make full use of the existing store of practical knowledge gathered over many years by skilled British craftsmen. It is our duty to examine the scientific reasons for practical experiences and to establish therefrom first principles which may be applied to the extension of knowledge about timbers and processes already in use, and to the investigation of new ones.

20. Timber is a highly complex organic structure. A particular piece of timber exhibits numerous variables which depend on the anatomical structure of the species and on the varying factors affecting the growth of the tree in the forest. To ascertain the qualities of a specific timber it is consequently necessary to undertake an extensive series of investigations, including, as a rule, investigations on specimens of commercial sizes. The difference in the structure and chemical composition of the wood of different species, and the variation in different samples of the same species, is reflected in differing physical and mechanical properties and in varying behaviour to treatments such as seasoning. This variability in timber in contrast with materials such as iron and steel necessitates repeated experiments on a large number of samples before it is possible to determine the average qualities of a specific timber. At the same time, in investigating a timber for some particular use, the range of inquiry can often be narrowed down by examination of the structure by a wood technologist, whereby it is possible to obtain a preliminary indication of the uses of the timber through its similarity to some known type.

Wood Technology and Timber Physics

21. Whether the timber is to undergo a complete investigation of all its qualities—of structure, seasoning, strength, durability, working—or is only to be investigated for some limited purpose, examination by the wood technologist is the first step to be taken. The limited purpose may be to identify the timber, or to indicate the possible uses of a new timber or to discover some variation or abnormality of structure responsible for the failure of a particular sample of a standard timber. To assist in the identification and comparison of species, there are available at the Imperial Forestry Institute some three thousand specimens whose identity has been authentically established, and from these the Institute and the Laboratory have co-operated in preparing type slides for the microscope, showing the minute structure. The immediate value of this work is illustrated by the number of demands each week made by the wood-using trades for the identification of unknown or doubtful samples.

22. These type slides showing microscopic structure are also of great assistance in classifying a new species for its probable uses or in suggesting a substitute for some timber that is becoming scarce. In both cases much time, labour and expense is saved, since the investigations on a new timber can be narrowed down to accord with probable uses, while possible substitutes for a known timber can be reduced to a small choice. For this correlation of structure with qualities, and for the examination of the variation of structure within the species, an interesting investigation is being conducted on oak, elm and ash. It is well known that some types of oak timber are hard, others milder; some cleave well, others do not; while some have a better figure than others. In co-operation with the Imperial Forestry Institute, it is hoped eventually to relate these differences with their causes, and thus guide the forester in his choice of variety, locality and silvicultural treatment. Similar investigations are carried out, as a routine, in correlating the results of strength tests with structure; and, as time allows, with reference to aptitude for seasoning, absorbing preservatives, and to its working qualities. A critical study of the structure is likewise a necessary preliminary to the investigations of the Timber Physicist. He needs the results of this study before he can determine the factors influencing the movement of moisture and heat within the timber, which are of special importance in the fundamental solution of seasoning problems, or before examining the hygroscopic power of wood with reference to shrinking and swelling. The "working" of wood consequent on its hygroscopic property is one of the urgent problems of the wood-using trades. Something can be done towards its solution by adequate seasoning; but an enormous amount of time, trouble and expense would be saved if a sure means could be found to render wood stable. We are therefore concentrating on this problem.

Seasoning

23. The next step in the general study of a particular timber is the examination of its aptitude for seasoning and the best means of achieving a satisfactory result. Some timbers season with ease, others with difficulty; and each must receive a treatment suited to its characteristics. For seasoning under atmospheric conditions this will affect the manner of piling in the yard. For seasoning under controlled conditions (kiln-seasoning) it will influence the method of drying in the kiln. Bad methods of seasoning are responsible for a large wastage of timber, perhaps only exceeded by losses due to decay; and in the reduction of waste and in realising the full commercial

value of a particular species, efficient seasoning occupies a most important place. The importance of this subject is reflected in the considerable body of work, described in detail in the Director's report, which the Laboratory is doing in connexion with the study of the seasoning properties of home-grown timbers, with methods of air-seasoning, principles of kiln seasoning, designs of kilns, kiln operation, correct moisture content of wood for different purposes, and so forth. A large number of inquiries have been dealt with by the Laboratory, and the timber industries would, we think, bear witness to the value of this work and the assistance we have already been able to afford.

Timber Mechanics

24. In the Section of Timber Mechanics the first step is to make mechanical tests on small specimens free from defects in order to determine what is called the inherent fibre strength of the species. The results give a measure of the optimum strength of the species in mechanical properties such as compression in different directions, bending, cleavability and so forth. They are used in comparing one species with another, in determining the influence of defects when testing large-sized timbers, and in computing the influence of rate of growth, density and moisture content. A full discussion of this aspect of timber mechanics may be found in our report just published, entitled *Project No. 1, Tests of Small Clear Specimens of Timbers.* In passing, it may be said that these tests are of particular interest to the Forestry Commission for ascertaining the value of the timber of the newer exotic species, as grown in this country, such as Douglas fir and Sitka spruce, and for determining what rate of growth will produce the best quality of timber.

25. The tests as carried out by this Laboratory are susceptible of comparison with those of the Laboratories of the United States, Canada, India, the Federated Malay States, South Africa and New Zealand, all of which have adopted as standard practice the use of the machines and methods of test first introduced at Madison. The American Laboratory was the pioneer in this and other fields and to it a debt of gratitude is owed for the assistance so willingly and courteously given to other Laboratories, including our own, in course of formation. We have also proposed to the British Engineering Standards Association the adoption of the specification of these tests as standard practice throughout this country. A sub-committee of the Association, on which the Laboratory is represented, has been examining the question and has drawn up a schedule which is shortly to be submitted to the full engineering panel of the Association. It will be possible to suggest several improvements for the consideration of the other national Laboratories.

26. Of the specialized mechanical tests, designed to prove a timber for some particular purpose, the most important that we have undertaken are those concerned with the use of certain home-grown species for pitprops. Reference to the progress report just published on this subject will show that the tests are uniformly in favour of most of the home-grown species tested, when compared with our tests on imported props. We believe that exploitation of British-grown timbers has suffered less because of their quality (though it is not yet agreed that certain introduced species, such as Corsican Pine and Douglas Fir, are suitable for pitprops) than to the insufficient and irregular supply and the high cost of delivery. The mechanical tests have been combined with a seasoning investigation and with an intensive survey of the coal fields by the Laboratory's Utilization Officer to determine the varying requirements of the different areas and the conditions under which the timber is used. All this work has been carried out in collaboration with the Forestry Commission, who supplied sample

props for practical tests in different mines. The tests on pitprops are of special importance to the Commission and other growers in this country in marketing the thinnings from their young woods.

27. Preliminary work has been done on the testing of structural timbers, in which account is taken of the influence of defects and the results of which are used in providing Tables of safe working stresses for the use of architects and builders. As above indicated, the preparation for this work is the testing of small specimens free from defects: later, when these tests are sufficiently advanced, further tests on structural material will follow.

Wood Preservation

28. We have experienced considerable delay in making a beginning with this subject, as it was not found possible to obtain a fully qualified man to take charge of the work. It was at length decided to train a member of the staff, a young engineer from the staff of the Timber Mechanics Section being selected. Accordingly, he was first sent to the Section at Oxford, for a short course in Wood Technology, and thence on a series of visits to certain commercial wood-preserving plants. Since then he has been under the instruction of the Director of Research—who has had considerable experience of this class of experimental work in India—in the operation of the experimental plant at the Laboratory. The programme of work in this subject comprises the study of the natural durability of different species of timber, the efficacy of different antiseptics, and the various methods of applying preservatives. One of its chief objects is to cheapen the process and thus widen its use. The work is closely co-ordinated with that of the Sections of Mycology and Entomology, which study wood-destroying fungi and beetles, and with the Section of Chemistry, which studies the chemical alterations in wood substance caused by these agencies.

Wood Working

29. In the effective marketing and utilization of a timber, something more is required than an examination of the physical and mechanical properties described in the preceding paragraphs. It is necessary to say how a given timber will behave under the tool and to determine what set of the saw or knife, for instance, or what machine speed will give the best results. The Director of Research has, therefore, drawn up a scheme of investigation, the object of which is to determine the working and finishing qualities of timbers according to definite standard methods which shall, as far as possible, eliminate the personal factor, enable true comparisons to be made, and allow of the tests being reproduced by other investigators. So far as is known this represents the first attempt to standardise such work, for it is only in recent years that owing to the greatly improved types of wood-working machines on the market, the working qualities of a wood have received the technical investigation they require. The project must be regarded as tentative, but it is hoped that with further experiene of technique it will be possible to eliminate the personal factor and place the conditions of test and the assessment of the results on a more standardised basis.

Mycology and Entomology

30. With reference to the Director's report on the Section of Mycology, we would draw attention to the issue of Bulletin No. 1, *Dry Rot in Wood*, drawn up in collaboration with Professor Percy Groom, F.R.S., the Building Research Station and H.M. Office of Works. Complaint is so general that we have been at pains to make known as widely and in as simple a form as possible the existing information concerning

the cause, prevention and cure of an evil which is responsible for heavy losses and for no small number of accidents. The treatment of dry-rot depends largely on the particular circumstances of attack attending each individual case, and in the less simple cases expert opinion is usually necessary. But prevention is better than cure, and, given an understanding of the conditions inviting decay, there is no doubt that attacks by dry rot can be materially reduced by proper care in construction and by quite simple precautions. We are continuing the study of the conditions and development of the organisms concerned, and the means of control. We are also preparing type cultures of the various wood-destroying fungi, type microscopic slides of wood after attack, with a collection of fruit bodies and type specimens of rot to assist rapid diagnosis. The Sections of Mycology and Entomology, mainly engaged in the study of the cause and conditions of decay, work closely with the Section of Wood Preservation, studying prevention and cure.

31. Perhaps the most interesting work at the present time is the co-operative work going on between the sections of Mycology and Entomology on the possible relationship between the attacks of fungi and beetles, with special reference to *Xestobium*, one of the furniture beetles. In every case of *Xestobium* attack examined to date, a fungus (not necessarily wood destroying) has also been found in the wood, and there may well exist a symbiotic relationship between the two organisms, an understanding of which will assist prevention of the attack.

32. The Director's report shows that considerable success has attended the investigations on the *Lyctus* beetles which are causing serious trouble particularly to the furniture manufacturing trade. We have been able to give a demonstration to the trade of a means of ridding their timber of this pest by a steam sterilization treatment in the kiln; and we hope later to be able to suggest a treatment that will also give immunity from further attack. Important progress has been made in the study of the life-history of this pest. Previous workers have shown that *Lyctus brunneus* lays its eggs only inside the pores of hardwoods; our own research further indicates that this is true also of *L. linearis*. We have also been able to show that there is a definite relationship between the size of pores in the different species of hardwoods and liability to attack. This fact enables us to say that certain timbers can be attacked while others will be immune.

Chemistry

33. The investigation of the hemicelluloses of timber was begun at the Imperial College, at an early stage of our work. During recent years it has been continued at St. Andrews University, under the supervision of the Chairman of the Board. A detailed account of the work will be found in the Director's report and the results have been embodied in four papers published in the *Biochemical Journal*. The essential object of this work is a scientific exploration of the compounds known collectively as the "hemicelluloses," which occur in wood. These compounds are much less resistant than cellulose and are present in woods to an extent which varies according to several factors, including the extent of lignification. The chemical constitution of hemicelluloses and their relationship to cellulose and to lignin have not yet been established and no scientific information is available on the changes undergone by these constituents during processes such as seasoning. The research is of a fundamental character, and considering the objective in view, its prosecution by the Board is highly desirable.

34. The chief project engaging the attention of the chemist at Oxford is one, carried out in co-operation with the section of Mycology, on the alterations taking place in wood-substance during the progress of decay. This we have only lately started, and it is too early to comment on the possible outcome. Chemical studies are also being made of the bore-meal or frass produced by wood-destroying insects. Both these investigations are being undertaken in the hope that better means of prevention may be indicated from a knowledge of the chemical alterations that take place in the wood.

Utilization

35. As we have said, the Section of Utilization is the link with the industry in building up cordial relations, carrying out commercial surveys to find out trade difficulties and indicate lines of research, in keeping research work practical, and in getting the best value for the cost of research by securing the application of its results. The range of inquiries coming to this Section—of which over 300 have been dealt with within the past two years—is very wide, covering as it does almost all aspects of utilization from the conversion of the log in the sawmill to its numberless uses, including the use of waste material. The success of this Section in the objects set out above has been most gratifying. We would particularly call attention to the work, described in the report of the Utilization Section appended, that has been done in connexion with the drawing up of specifications for Empire timbers, following the order that preference shall be given to these by all Departments of State. We would also call attention to the investigation, described in the Director's report, on charcoal-making in portable kilns and on the design of such kilns. This work, in which the Fuel Research Board is co-operating, concerns the provision of a cheap and easily operated method of making charcoal for fuel to be used for making producer gas, as a source of power for motor vehicles and stationary engines. A successful result may lead to the more profitable utilization of forest and mill waste, which in many cases not only produces no revenue, but is a source of expense in its removal or destruction ; it will assist the British manufacturer of portable kilns ; and it will provide information eagerly sought by foresters and others in certain localities of the Dominions and Colonies where petrol is costly or difficult to obtain and where, on the other hand, wood is abundant. A series of experiments has enabled instructions to be drawn up for the operation of four different types of kilns, and has produced information which it is hoped will lead to considerable improvement in design.

Publications and Records

36. We should not conclude this review of the technical sections of the Laboratory without reference to the importance of a good system of permanent records, not only in keeping the Laboratory staff abreast of research progress in this and other countries, but in enabling up-to-date information to be rapidly supplied to inquirers. During the past three years we have been able to build up records that can now be said to be fairly complete, and a good technical Library.

Advisory Work for other Home Departments

37. In addition to work for the Forestry Commission, advisory work has been carried out for H.M. Office of Works (timber selection, specifications for building timber), the Ministries of Health of England and Scotland (specifications for building timber,

dry-rot), War Office (wood preservation), Air Ministry (seasoning, decay, revision of timber specifications), and the Ministry of Home Affairs, Northern Ireland (specifications for building timber).

Assistance to other Parts of the Empire

38. Assistance has been given to other parts of the Empire. Two officers trained in seasoning have been supplied, one to Burma and the other to Kenya. One officer trained in Timber Mechanics has been supplied to the Federated Malay States, and a mycologist to the Amani Institute, Tanganyika. Five officers from Forest Services overseas have attended the Laboratory for courses of instruction—namely, one each from India (seasoning), Trinidad (general), Ceylon (seasoning), and two from Nigeria (utilization and seasoning). On behalf of the India Office, Colonial Office and Crown Agents to the Colonies, the Laboratory has scrutinized tenders for the purchase of timber-testing machines, kiln-drying plant and other equipment and has advised on the purchase. Designs and estimates for a saw-mill and kiln plant were supplied to British Honduras. Advisory work in connexion with uses or markets in this country has been carried out for India (various), Burma (shunting poles for British railways), Australasia (uses, markets, charcoal making, equipment), British Honduras (uses and markets), Trinidad (markets), Kenya (portable charcoal kilns), West Africa (special uses), British North Borneo (uses).

Future Annual Reports

39. It has seemed right, in this our first annual report, to endeavour to convey a full picture of the history, development and operation of forest products research. Future reports will contain an annual survey of progress, while the Director's reports will supply the details needed to enable the wood-using industries and others technically interested to keep abreast of our work.

J. C. IRVINE,
(*Chairman*).

30th September, 1928.

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR THE PERIOD ENDED 30TH SEPTEMBER, 1928

INTRODUCTION

As explained in the Board's Report, the history of the Forest Products Research Laboratory may be divided into three periods. The first period was occupied with a survey of the field of work, leading to the submission of definite proposals for the establishment of a Government Research Laboratory. During the second period, a nucleus laboratory was set up and housed in the Royal Aircraft Establishment at Farnborough, and it was at the commencement of this period, in October, 1925, that the writer took over charge from Lieut.-Colonel Sir David Prain, C.M.G., C.I.E., F.R.S. The third period began with the transfer of the Laboratory from Farnborough to its new premises at Princes Risborough. An outline of the development that has taken place has been given in the Board's Report. It is only proposed in this Introduction to survey very briefly the present position before reporting in detail on the various lines of activity.

The period during which work was carried out in the Royal Aircraft Establishment at Farnborough was of the greatest value ; for, although at the commencement only very limited staff and equipment were available, time was allowed in which to collect and train staff, and to make a survey of the economic position as existing in the wood-working and timber industries, on which to base a programme of work. In the meantime the buildings were being erected at the new station, and preliminary arrangements were made early in 1927 by H.M. Office of Works to transfer all equipment, including testing machines, seasoning kilns, instruments, stores and furniture, enabling the staff to move over into their new quarters by the end of June of the same year.

It is desired to place on record a tribute to the invaluable work undertaken by the first Director, Sir David Prain, under whose wise and patient guidance the preliminary survey of the field of research and the initial experimental investigations were carried to a stage which made it possible to submit for sanction a complete scheme for a Forest Products Research Laboratory. Thanks are also due to the Air Ministry for providing temporary accommodation in the Royal Aircraft Establishment, and to the former Superintendent, Mr. Sidney Smith, and to his staff, for ungrudging assistance and much kindness.

In common with other research institutions under the Department, care has been taken, as stated in the Board's Report, to co-operate as fully as possible with organizations, especially those under State or University control, interested in related subjects, and to secure the assistance of recognized experience in various lines of work. At the beginning of 1927, the subsections of the Laboratory of Wood Technology, Timber Physics and Entomology were all working at the Imperial Forestry Institute, Oxford, where Professor C. C. Forsaith, of the New York College of Forestry, Syracuse, New York, had been engaged for one year in developing and organizing the work on wood structure. The arrangement has since undergone some

change, consequent on the creation of a full section, still at Oxford, of Wood Technology. The entomological work has been transferred to Princes Risborough, though it remains under the general supervision of Dr. J. W. Munro, of the Imperial College of Science and Technology. The mycological work is under the supervision of Professor Percy Groom, F.R.S., at the same College. Sir James Irvine continues to supervise at St. Andrews University special investigations on hemicelluloses. It is desired to take this opportunity of expressing appreciation for the valuable assistance readily given in these ways. The closest co-operation is maintained between the Forestry Commission and the Laboratory. Under the working arrangement originally made with Lord Lovat, the Laboratory undertakes the Commission's most urgent problems in utilization, the Commission supplying all material free of charge. This arrangement has been ratified by the new Chairman of the Commission, Lord Clinton. It has proved very sound and has greatly facilitated progress. The Utilization Officers of both organizations keep in close touch and collaborate in joint investigations for the benefit of all concerned in furthering the use of home-grown timber. Close co-operation is maintained with the Imperial Institute, and the Laboratory is represented on its Advisory Committee on Timbers. The co-operation extends also to exhibition work, and the joint exhibition with the Imperial Forestry Institute and the Imperial Institute on Empire Timbers has attracted a great deal of attention.

On 30th September, 1928, the staff of the Laboratory, including those stationed at London and Oxford, numbered 133, made up as follows :—

Scientific and Technical Staff, 40 ; Laboratory Assistants and boys, 17 ; Office Staff, 17 ; Industrial Staff, 59. A list is given in Appendix I.

A plan of the buildings at Princes Risborough is reproduced in the Frontispiece. Some idea of the equipment of the Laboratory will be gained from the figures and descriptions in the body of this report.

The organization of the Laboratory, with the main purposes of the various Sections, may be set out as follows :—

A. General Services

Office, Library and Permanent Records.
Drawing Office, Photography, Stores.
Engineering, Saw mill and Woodworking.

B. Technical Sections

Group I—

i. Wood Technology :—

(*a*) Identification.
(*b*) Relation of structure to the properties of wood.
(*c*) Classification for uses of little known woods by anatomical structure.

ii. Timber Physics :—

The study of the physical properties of wood, specially in relation to moisture and heat, basic principles of seasoning.

iii. Seasoning :—

Practice of air-seasoning and kiln-drying : kiln design.

Group II—

i. Timber Mechanics :—

(*a*) Comparative strength of timbers.

(*b*) Tests on structural sizes to determine influence of defects.

(*c*) Special tests for specific uses.

ii. Wood Preservation :—

(*a*) Durability ; in natural state and after antiseptic treatment.

(*b*) Toxicity of antiseptics.

iii. Wood Working :—

Sawing, machining, and finishing tests.

Group III—

i. Pathology :—

(*a*) Decay caused by fungi.

(*b*) Attacks by insects.

ii. Chemistry of Wood :—

(*a*) Wood analysis.

(*b*) Derivatives of wood.

(*c*) Chemical changes due to seasoning, or to attack by fungi and insects.

Group IV—

Utilization :—

(*a*) Liaison with industry.

(*b*) Industrial investigations to confirm uses and to suggest markets.

An account of the work of the technical sections, and of the progress to date is given under these headings.

It should be added that, for specific lines of work, schemes of operation (" projects ") are carefully drawn up so as to ensure at the outset that all aspects receive due consideration and that the allocation of work amongst the various Sections is such as to enable uniform progress to be made.

The establishment of a fully organized and equipped Forest Products Research Laboratory, where it is possible to study the qualities and characteristics of timber from widely different aspects, at once attracted the attention of those interested in timber not only in this country, but also abroad. This is evidenced by the immediate enlargement in the volume of inquiries received, covering a wide range of subjects, and by the increasing number of visitors to the Laboratory. It is not yet possible to supply definite information to all inquirers, as past records are meagre and the collection of fresh data must wait on the results of the further investigations now in hand.

Wood Technology

A knowledge of the structure of wood affords the only reliable means of distinguishing the different kinds from one another. Colour, weight, smell and other features may be helpful, but cannot be relied upon alone. Moreover, nearly all the differences in technical properties observable between the various woods can be traced back to differences of structure.

In describing the activities of the Laboratory in relation to wood technology, use will be made of a number of technical terms which can be conveniently explained in a short description of the structure of wood.

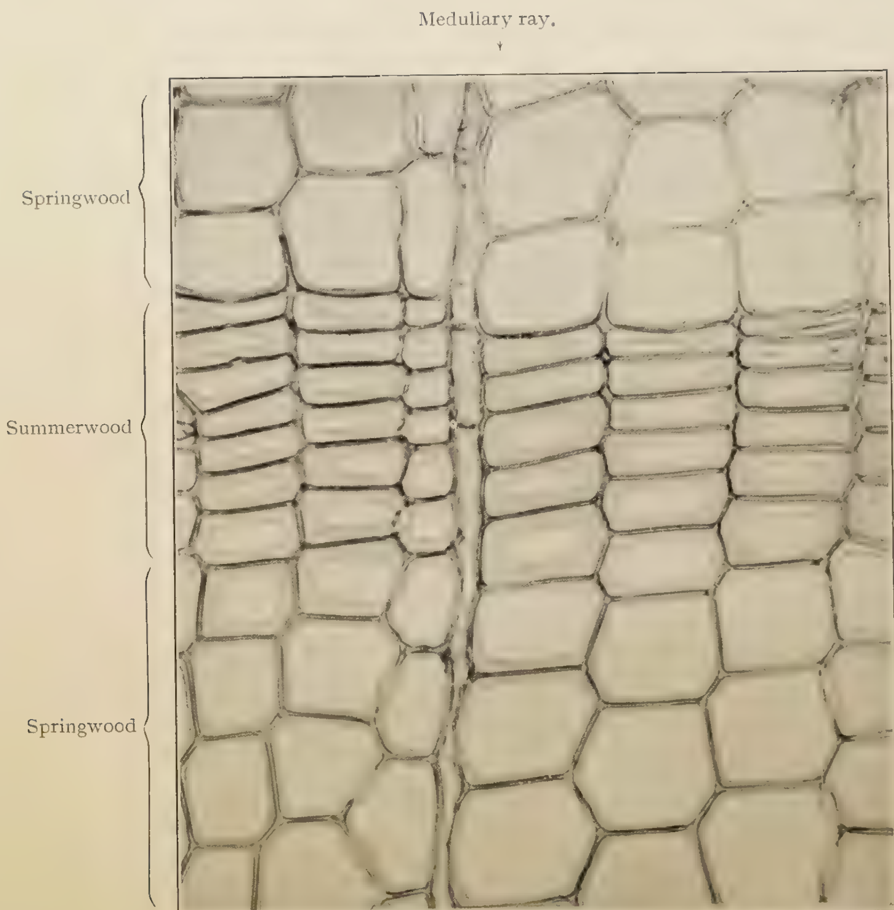


FIG. 1.—Transverse Section of Wood of Douglas Fir (Magnification 375) showing the different layers of the cell walls.

Wood Structure

Wood is made up of various kinds of minute, tube-like elements of different lengths and shapes, with walls of different thickness and cavities of different dimensions. These cells or wood elements, of which several kinds can be recognized, are so closely packed and cemented together as to leave only minute intervening spaces here and there. Wood is far from being a homogeneous material.

In the so-called "softwoods" (coniferous timbers), the wood consists mainly of "tracheids," long narrow cells having a diameter of about 0·03 mm. and a length about one hundred times greater, which serve the double purpose of giving strength to the tree and conducting water. Communication from tracheid to tracheid is by means of characteristic structures called "bordered pits" in the party wall of overlapping tracheids.

In the "hardwoods" (broad-leaved trees), the functions of strengthening and water conduction are carried out by two different types of cell. The "fibres," generally narrower than tracheids and about 1 mm. in length, give strength and stiffness to the wood, while water conduction is carried out by "vessels" which are commonly called "pores" when seen on an end surface. The vessels may be as much as 1 mm. in diameter, and are of indefinite length, being composite structures built up from a series of cells. In some woods, the larger spring-wood vessels form a well-marked zone or band; such woods are called "ring-porous." In others, the pores are more uniform in size and distribution; these are termed "diffuse-porous."

Both hardwoods and softwoods contain tissue composed of brick-shaped cells—the "parenchyma"—which in the sapwood is living and serves among other purposes for the storage of food. The parenchyma falls into two distinct groups: it may be distributed vertically in the wood either in isolated strands or associated with vessels—this is the "wood parenchyma"; while in all woods it forms the "medullary rays" (see Fig. 1), which are narrow, radially disposed ribbons of tissue, giving to many species a characteristic silver grain on the radial surface.

On the cross-section of a temperate climate tree concentric rings are generally visible, which mark the growth increments of successive years. The first formed tissue of the "annual rings," the "spring wood," is generally composed of cells of larger diameter and thinner walls than those forming the much denser tissue, the "summer wood," produced at the end of the growing season.

Identification of Wood

One of the first essentials in forest products research work is the correct naming of the material handled, since much of the research on wood structure can be reduced in value or even rendered worthless by faulty identification. This applies not only to home-grown timbers, where great care is necessary in collecting material for structural investigations when dealing with such genera as elm, oak and poplar, in which many varieties and hybrids are known, but also to the identification of imported timbers, especially those from tropical countries where confusion has frequently arisen in the past because the identification of a wood with a botanical species has been based on such insecure foundations as a native name that frequently covers more than one species. To establish a collection of correctly identified woods the Imperial Forestry Institute has developed a scheme whereby the Dominions and Colonies send home samples of wood from trees of which material has been preserved for botanical identification. Concurrently, information is collected in the country of origin to supplement present information on quantity available, accessibility and cost of extraction; this should be of considerable value for the newer and less well-known woods.

The collection of identified wood specimens housed at the Imperial Forestry Institute has now increased to some three thousand specimens, and fresh material is continually being added. This number falls short of timbers which eventually will come to be of commercial importance either from the point of view of value or of quantity, and much work remains to be done before a really representative collection of the timbers of the world will be available for study.

Microscopic sections prepared from wood samples so collected provide the basis for the identification of unknown woods. Before, however, such a collection can be used satisfactorily for this purpose, it has been found that considerable experience is necessary in recognising structural differences between woods and in the preparation of keys as an aid to identification.

The chief structural characteristics of wood which have been found of most value in identification include the presence or absence and the size and distribution of vessels, wood parenchyma, and resin canals ; the size and structure of the medullary rays ; and the size, shape, and number of pits and other sculpturings on the cell walls. Keys based on such characters have been published at various times for the identification of the commoner or the more important timbers of different countries. Among these may be mentioned those of Hartig for European, Record for North American, and Brown for Indian timbers. Such keys have their limitations, and at present the identification of a specimen of an unknown wood is not generally practicable without access to a collection of authenticated wood specimens and prepared microscope sections supplemented, when this is possible, by reference to such works as Gamble on Indian timbers, Moll and Janssonius on the Javanese woods, and Record and Mell on those of the tropics of the New World.

To those who are acquainted with the difficulties which are met with in the identification of woods, there is no need to point out that identification from wood samples cannot be made with the same precision as from botanical material, owing to the frequent absence of clear-cut specific or even generic differences. While, however, a precise identification is often impossible, it is generally possible to obtain an identification sufficiently close for commercial purposes. For instance, among the hundred odd species of the genus *Pinus*, a specimen of pine wood can be classed as belonging to one of three groups of which the soft pines and the pitch pines are the two most important : with additional information as to the country of origin it is generally possible to narrow down the identification to a small group of species marketed under one commercial name. Much the same applies to oaks and eucalypts.

It will not be out of place to mention at this point a few of the advantages that the existence of a collection of woods of the type described has been found to have in the commercial world. During the handling of the collection much information about the different woods has already accumulated, and with the added information derived from the microscopic structure it is possible to give suggestions as to new or substitute woods for different purposes either in the interest of economy or to take the place of those whose supply is dwindling. From a consideration of a series of photomicrographs of wood sections, the Research Station at Dehra Dun found it possible to select from the four hundred or so commercial woods of India about six which could be used for certain purposes in place of boxwood (*Buxus*). It was also found at Dehra Dun that wood structure was of considerable assistance in wood preservation, in that the most suitable method of treatment for any particular timber could be determined with quite fair accuracy from an examination of photomicrographs of the wood structure.

Correct identification is of value from a somewhat different aspect. Vernacular names are frequently local, and the same timber may come on the market under

several names, all of which are not equally well known. Correct identification will prevent confusion arising among both buyers and sellers, who may not always realize that they are dealing with the same timber. Again, little-known woods are frequently placed on the market under names the same as, or similar to, those of well-known kinds.

Variability in Wood Structure

When the wood of any particular species is closely studied, a considerable range in structural variation is disclosed ; not only does the width of the annual rings often vary enormously from year to year, but other structural features show an equally wide range, related no doubt to the conditions under which the tree was grown. To mention a few such characters, the volume occupied by the medullary rays is very much less in suppressed trees than in dominant trees ; in British oak there is a large variation in the proportion of fibrous tissue ; under sub-alpine conditions woods which are normally diffuse-porous tend to become ring-porous ; the average thickness of the cell wall does not remain constant within a species ; and, finally, structure varies somewhat with the position in the tree.

It is the variation in such characters as these which accounts, no doubt, for the large range in strength values which nearly all species of wood exhibit, for the preferences shown in the trade for wood from certain localities, and for the prejudices against wood of apparently similar type from other localities. The discrimination which is exercised in the selection of willow for making cricket bats, ash for tennis rackets and other sports requisites, and oak for cabinet work is, of course, well known.

In all questions of the utilization of wood it is necessary to determine the basis of these preferences and prejudices, in order to obtain the best market for the quality of the timber which can be grown in the country, and to supply the quality most suited to the particular needs of the customer. At the present moment there is no definite knowledge of the structural variation which is normal for trees native to or grown in Great Britain, nor any certainty as to the effects due to climate, silvicultural methods, and local conditions, nor of the effects due to the occurrence of sub-species and local races, and hybridization. To obtain information on this subject an investigation has been started on the effect of these factors on some of the more important timber trees in Great Britain, and on the relation between variation of structure and variation in the more important economic properties, such as strength, seasoning, and wood-working qualities.

The outcome of this investigation will be valuable in two distinct aspects. Not only will the timber-user be helped in the choice of the most suitable material for his purpose, but also, with the co-operation of the forester, it should be possible to lay down what cultural variety of a species, what soils, and what silvicultural methods should be chosen to produce the quality of timber which will yield the greatest profit to the grower and be most suitable to the consumer and the development of a market.

To illustrate the kind of value this research is likely to have, two concrete examples will be given.

In the structural examination of the material used in the investigation of the strength properties of timbers grown in Great Britain, the relation between strength and the proportion of fibre was confirmed in oak, and from the appearance of smooth transverse sections or end surfaces it is possible for anyone who is familiar with the structural characters to arrange a series of samples very closely in the order of their relative strengths.

The next illustration emphasizes an aspect which is of interest to the forester. Recently a series of tests were carried out by the Laboratory at Princes Risborough on the relative strength of pitprops of home-grown Douglas fir for comparison with other timbers. It has been established by work at the Laboratory that for many woods maximum strength is definitely correlated with a definite ring width (see page 41).

In this country it would seem that the growth of Douglas fir under certain climatic and soil conditions is more rapid in early life than in its native home, and produces a timber of ring-width which is in excess of the known optimum for maximum strength. From a study of the range of conditions under which Douglas fir grows in its own country, it may be possible by selecting suitable localities and by adapting present silvicultural methods to reduce the rate of growth of Douglas fir sufficiently to bring the timber within the ring-width class correlated with maximum strength.

Besides its relation to mechanical properties and to questions of utilization, wood structure and its variation is being studied also for its influence on the seasoning qualities of wood.

The number and size of the medullary rays in wood have a considerable effect on the occurrence of checking during the seasoning process. This is very noticeable in oak, where in some seasoning experiments it was shown that timber with a larger proportion of the broad medullary rays is much more prone to check than timber where this proportion is smaller. These large rays form planes of weakness along which splitting takes place to relieve the stresses set up by shrinkage across the grain, due to loss of moisture, during the course of drying.

The presence of knots and the occurrence of irregularities in the direction of the grain increase the liability of wood to warp during seasoning. The excessive warping shown by elm may, however, be due in part to other causes, such as the relation of shrinkage, on moisture loss, to local variations in structure and density or to a peculiar form of defect known as "collapse." It will not be possible to say more on this particular subject until the relation of the shrinkage of this wood to moisture content has been studied in greater detail.

Timber Physics

The Timber Physics Section of the Laboratory deals with the study of the physical and physico-chemical properties of wood, other than its mechanical properties.

The substance of which wood is composed contains a number of different constituents. But, taking these collectively, it may be described as a translucent, horny material of a pale brownish colour, with a specific gravity of about 1·54. By suitable treatment of wood flour it can be obtained as a solid homogeneous material, but with its physical and chemical properties somewhat modified.

The chemical nature of wood substance is far from being determined. The most distinctive feature is the carbohydrate, cellulose, which forms from 50 to 60 per cent. of the dry weight of all woods. This cellulose can be isolated and is probably identical with the cellulose obtained from cotton, though this has not been definitely confirmed. The remaining 50 to 40 per cent. of wood substance is composed of other carbohydrates and residues of aromatic nature.

Recent X-ray analyses of the structure of purified cellulose obtained from plant

fibres have shown it to consist of chains of glucose units lying side by side and parallel to the length of the fibre. Chemical bonds unite the glucose units to each other, but the individual chains are held together by the weaker bonds of residual valencies. These results agree with Naegeli's micellar theory of plant membranes and make it intelligible why wood and plant fibres, when they absorb moisture, expand in directions at right angles to the length of the fibre, but practically not at all in the direction parallel to their length.

Although the chemical process of the lignification of the cellulose cell wall is far from being understood, it would appear from X-ray studies that there is little distortion of the cellulose lattice during this process.

The material of which wood is composed belongs to the class of substances known as colloids. Like most colloids, wood substance takes up water and swells. It differs from the colloid gum arabic in that the amount of water it takes up, and hence its swelling, is limited ; and from gelatine in that it does not pass into the sol state when the temperature is raised.

When wood substance takes up water the increase in volume is somewhat less—by some 5 per cent.—than that of the water concerned, and, from thermodynamical considerations, it can be shown that there is relationship between the deficit in the increase in volume and the heat evolved during the process. When wood is dried, energy has to be supplied to remove the water, and as the water becomes less, the greater is the amount of energy required.

The structure of a piece of wood may modify or even mask these properties of wood substance. It has been shown above that wood is composed of cells differing considerably in their shape, dimension and arrangement within the wood, and that the structural features vary not only from species to species but in different samples of the same species and even in samples from the same tree. Moreover, a piece of wood is not solid ; a third of the volume of a sample of average density consists of wood substance, the remaining two-thirds being air space. Lastly, even the wood substance itself is not a homogeneous material : the central portion of the cell wall differs from the portions bordering on the cell cavities in being more highly refractive to light and in reacting differently to stains and other reagents. Figure 1, showing the general distribution of wood substance in a softwood, also shows these differing portions of the cell wall. It would appear that the middle of the cell wall acts as a more rigid framework, and that the volume loss of the wood substance is masked by the outer layers of the cell wall shrinking on to this framework when the wood loses moisture.

The variability in the number, character and disposal of the cells making up a piece of wood explains the broad differences in amount of shrinkage and swelling shown by the different species, while it is possible that unexpected differences in behaviour, such as the fact that in general the denser a wood the greater will be its shrinkage from the green to the oven-dry condition, may be explained by the differences in the physical properties of the two distinct regions of the cell wall.

Some of the experiments undertaken may now be described.

Moisture Movement in Wood.

Up to date, the main physics work of the Laboratory has centred round the movement of moisture in wood.

In a very wet piece of green wood, the weight of water present may be double or more the weight of the dry material. In a freshly felled tree this water is present in the wood as (1) *free water* in the cell cavities and (2) *water absorbed* by the cell walls.

When a wood-cell dries, the free water contained in the cell cavity evaporates first, then the water absorbed in the cell walls. Except, perhaps, in certain timbers, the abstraction of the free water does not cause any shrinkage or other dimensional change in the cell. The stage of moisture content reached when the cell cavities are empty of free water and the cell walls still saturated has been termed the " fibre saturation " point. In this condition the amount of moisture present, though varying with the species, is usually from 25 to a little over 30 per cent. of the dry weight of the wood. It is the abstraction of the water from the cell walls that causes shrinkage, and, as will be shown later (see page 33), this shrinkage plays an important part not only in the problem of seasoning, but also in the study of the critical changes in the strength and other properties of timber.

When wood has been drying for some little time the outer layers of the wood have a moisture content approaching that which it would have when in equilibrium with the humidity of the surrounding air ; inside, there will be a core where the moisture content has hardly altered ; while intermediately, there will be a zone with a moisture content gradually rising to the fibre saturation point on passing from the surface inwards. The moisture leaves the surface in the form of vapour ; the moisture to replace this loss must pass through the intermediate zone by combined diffusion through the substance of the cell walls and the air in the cell cavities ; this moisture is in its turn replaced to some extent by moisture from the central portion by capillarity. The relative importance of the part played by diffusion and by capillarity depend on the nature of the particular wood. In Scots pine diffusion is probably the more important, as there is a sharp break in moisture content at the fibre saturation point on passing from the intermediate to the central zone.

Numerous experiments have been carried out in order to determine what are the factors which control moisture movement in wood. The experiments at the Laboratory have comprised both the measurements on the rates of passage of moisture through wood under controlled conditions, and the drying of small specimens of wood thoroughly saturated with water, also under carefully controlled conditions of temperature and relative humidity.

In the first, measurements were made of the rate of passage of moisture, under conditions of steady linear flow, through pieces of timber, the vapour pressures at the opposite end faces being maintained at different values. The figures obtained for a series of cylindrical straight grained oak pieces (varying from 2·0 to 0·5 inches in length) indicated that the flow along the grain was largely of the nature of molecular diffusion. If the rate of flow be written as $\frac{K\ (p_0 - p_1)}{L}$, where p_0 and p_1 are the vapour pressures expressed as percentage relative humidities, at the opposite ends of the cylindrical plugs, and L is the length of the plug in inches, the magnitude of the coefficient K is given by the following table :—

Length (in.)	Rate of flow gm/day/sq. inch.	K.
2·0	0·143	0·00368
1·5	0·179	0·00372
1·0	0·234	0·00369
0·75	0·282	0·00374
0·5	0·343	0·00369

Across the grain, and along the grain in denser oak, the value of K was found to vary with different values of p_0 and p_1. The above results are stated and discussed in a publication [(1)*] already issued by the Department.

* The numbers relate to the references at the end of each section.

In the second series of experiments, the effect was investigated of various factors on the passage of moisture through the heartwood of Scots pine, when a steady flow had been obtained. After allowance was made for an assumed surface effect, the flow of moisture through a piece of wood was found to be inversely proportional to its thickness when the moisture content of the air at the two opposite faces was kept constant but at different values. Keeping the thickness constant, the rate of flow was directly proportional to the difference in the moisture content of the air at the opposite faces. It was found also that the diffusivity of moisture in wood appeared to vary with the moisture content, and had a value at " fibre saturation " nearly six times as great as when dry. The relation between diffusivity and moisture content was only approximately linear and was more nearly represented by a parabolic formula. From a comparison of the diameter of the cylinders with the moisture content at a specific distance from the exposed face it was seen that change in dimension was directly proportional to change in moisture content below fibre saturation. These results may have a direct bearing on the practical problems of kiln-drying (see page 23).

Hygroscopicity of Wood

The substance composing the cell walls of wood is hygroscopic, and has an affinity for moisture. up to an amount which bears a definite relation to the relative humidity of the surrounding air. If the amount of water contained in the walls at any time is less or more than that appropriate to humidity of the air, further moisture will be taken from or given up to the air until a condition of equilibrium is established between the moisture of the wood and of the air.

Under normal conditions, the relative humidity of air, whether indoors or out, is almost constantly changing, and so the moisture content of exposed wood will also vary continually in an endeavour to maintain the disturbed equilibrium. Practically, the ensuing variation in moisture content of wood is of less importance than the shrinking and swelling, or " working " as it is termed, which accompanies it. The elimination or reduction of this troublesome feature would be of great economic importance. While many processes for the purpose have been suggested, their claims have by no means been fully substantiated, and much remains to be done in determining the factors which are chiefly concerned in the " working." Some time has been expended in devising suitable methods and apparatus for this study.

Shrinkage and Swelling of Wood

The work on the shrinkage and swelling of wood, and on " collapse " (see page 18), has been mainly of a preliminary nature in order to survey the field and gain an insight into the character of the problem. Sufficient evidence has been collected to show that the amount of shrinkage from the green condition depends largely not only on the conditions of drying, but also on the structure and the species. In this connexion experiments have recently been started on the influence of temperature on the volume of shrinkage in elm and to determine how far dimensional changes are reversible. Samples, so selected as to cover a suitable range of structural features, are being exposed periodically to a specified cycle of changes. Further experiments on similar lines are being carried out on elm, oak and on various conifers to determine the effect of structural variation and species.

Thermal and Electrical Conductivity of Wood

The measurement of the thermal conductivity of wood is rendered difficult by the fact that, when a heat gradient is set up in a piece of wood, a redistribution of the contained moisture naturally occurs. For this and other reasons attention is being confined, in the

first instance, to the measurement of thermal diffusivity. Diffusion plays a part in many practical problems, for example in the calculation of the time required to heat up loads in the seasoning kiln, especially where sterilization by heat is to be used to combat insect infestation (see page 55).

Some preliminary measurements are being made on the electrical conductivity of wood samples, as a means for determining their moisture content.

(1) STILLWELL, S. T. C. Movement of Moisture with reference to Timber Seasoning. *Forest Products Research Technical Paper No.* 1. H.M. Stationery Office, price 1*s*. 6*d*. net.

(2) MARTLEY, J. F. Moisture Movement through Wood—The Steady State. *Forest Products Technical Paper No.* 2. H.M. Stationery Office, price 1*s*. 3*d*. net.

SEASONING

Introduction

Although under normal conditions of use wood always contains some moisture, the amount is almost invariably less than that held in its growing state. In general, as soon as a tree is felled its timber begins to lose moisture, fairly rapidly at first and then more slowly. Finally a state is reached when the amount of contained moisture remains roughly constant, although it may vary to some extent with changes in the surrounding atmosphere. The loss of moisture after felling is commonly known as the seasoning process.

For a few specialised uses it is better to use timber in its green or unseasoned condition, as, for example, for piles, lock-gates, etc., where the timber is in continual contact with water. Occasionally it is desirable to use only partly seasoned material. In pit-prop timbers, for instance, a certain amount of seasoning is an advantage as giving lightness to the props, but it is better not to carry the seasoning process too far, since partly-dried timbers give more warning of collapse under a load than those which are more thoroughly dried. For most purposes, however, it is desirable that the wood should be well seasoned before it is used, and for many purposes it is essential that it should be so treated.

The main advantages of seasoned, as compared with green or unseasoned wood, lie in its greater lightness, its greater general strength and hardness, its immunity from, or greater resistance to, fungal attack, and its greater stability. Except in special cases, there are practically no disadvantages to set against these important gains, and, consequently, it is not surprising that the desirability of seasoning timber has long been known and recognised.

Until recently, in spite of its importance and its long and widespread usage, the process of seasoning has never held its due place as an essential part of a scheme of production or manufacture. It is interesting to note how often in a highly organised wood-using factory, fitted with up-to-date machinery for production, the seasoning is either being carried out at a very low standard of efficiency, or else that any improvements in the seasoning operation are made only when developments in other processes of the manufacture have come to a temporary standstill.

Perhaps it is partly as a result of the disregard of its economic aspect in the past that scant attention has been paid to the technical side and that little knowledge has been gained as to how seasoning takes place and as to the factors which control its progress. This was, perhaps, of less importance when the only method of drying timber was by air-seasoning. At any rate, it is only in recent years and coincident with the advent of modern kiln drying, that serious investigation of the technical and scientific aspects of the seasoning process has been made.

The Problem of Seasoning

The problem of seasoning timber is rendered difficult by the fact that, as already explained (see page 20), after a certain stage is reached in the process of drying, any further loss of moisture is accompanied by a shrinkage of the cellular structure. Though the shrinkage occurs mainly in the plane of the cross section and only to a negligible amount in the direction of the grain, this does not greatly simplify matters. The shrinkage, together with the fact that moisture does not move freely from point to point inside the timber, results in stresses being set up which may become sufficiently great to cause serious damage.

If a piece of wet timber is exposed so that it can dry freely, moisture will be evaporated from the surface, and the outermost layer will dry comparatively quickly. Whilst the moisture occupying the spaces between the walls of the structure is being evaporated, no change of dimensions takes place, but when this moisture is all gone, and that contained, more intimately, in the cell material itself begins to dry out, there is at once a tendency to shrinkage, a tendency which increases as the drying of the particular layer proceeds further. This tendency of the outer layer to shrink is resisted by the wetter adjacent layers, and a tension is set up, which is not harmful if kept within limits. If, however, the tension becomes sufficiently great, it may cause damage even to the extent of breaking down the structure and forming the splits and checks familiar enough in too rapidly seasoned timber. In the meantime, when the drying of the surface has proceeded awhile, moisture begins to move to it from within the timber itself from the adjoining layers, thus helping to mitigate the effects of further evaporation ; in fact, if the evaporation is not too rapid, the transfusion of moisture may become sufficient to put a limit to the stress resulting from further surface drying.

This conception forms the basis of the ideal seasoning operation. The rate of evaporation from the surface must be controlled by proper choice of the humidity of the surrounding air so that the stresses set up in the timber are kept within suitable bounds.

There are, however, numerous difficulties in the way of a fundamental solution of the problem of seasoning. Investigation is required of surface evaporations, of stresses and strains related to moisture content, of the magnitude of permissible stresses, of shrinkage, and lastly of the movement of moisture within the timber, considered not only in regard to the physical laws which govern it, but also in relation to the anatomical structure of the particular timber under consideration. On some, if not on all of these points, practically no information is, at present, available. These fundamental studies are considered more fully under Timber Physics (see page 19).

The Empirical Solution

Although the detailed study of the factors involved in the seasoning process is thus at its beginning, the general principles involved are fairly evident.

Starting from these principles it is possible to lay down beforehand a practical procedure which will prove more or less successful. This partial solution is capable of general application in a limited sense only, for it requires the additional knowledge of factors peculiar to the species, dimensions and other features of the particular timber concerned. The shortest route to such knowledge is through experimental investigation carried out in a systematic and careful manner. There is an alternative choice as to the scale on which the experiments may be carried out. On the one hand, small scale or laboratory methods may be used, or on the other the tests may be made on a scale directly comparable with commercial operations. The first has the advantage

in economy of material and effort, but its results are not always similar to those given by larger scale work. The laboratory type of experiment is, therefore, regarded as merely preliminary to a full scale test, the latter being the real basis for the final results to be published and used.

The Commercial Position of Seasoning

It may now be interesting to glance at the present commercial situation, more especially as this also concerns other phases of the work in progress.

The oldest way of drying timber was by what is now called air-seasoning, or (misnamed) natural seasoning, to distinguish it from the newer practice of kiln or artificial drying. In its general form—direct exposure of the timber to atmospheric conditions—air-seasoning represents a simple though technically crude process. When successful, it owes its success to the slowness with which the drying takes place, rather than to the precision with which the factors that govern the drying are controlled. In temperate climates, however, it is a safe and easy method of seasoning many species of timber. Its main disadvantages are that it is very slow; that its progress is dependent on the climatic conditions, the extreme variations of which may be too severe for some, if not all species; and lastly, that as a process of seasoning it is not complete, so that very often a further drying or a conditioning treatment is essential. These disadvantages were always recognized, and attempts were made to overcome the slowness and the incompleteness of air-seasoning by more or less elementary methods which may be said to be the forerunners of modern kiln drying and conditioning treatments. These disadvantages, too, have become emphasized by the needs of modern intensive production methods, and the necessity for lower and more precise standards of moisture content in certain timbers, which has resulted from the better and more uniform heating of houses and public buildings. The demand for a surer method, such as is afforded by modern kiln-drying and conditioning processes, is extending among the wood-using industries.

Unlike air-seasoning, kiln-seasoning when properly carried out, so far from being a crude operation, is a highly technical one. The factors which give it the advantage of greater speed of operation and higher quality of finished product may re-act to the greater detriment of the timber if they are improperly applied or controlled. Sufficient research work has, however, now been done to show that the new process is a commercially practicable proposition, with many advantages. At the same time, it must not be forgotten that from the commercial viewpoint it is not sufficient that a process should have technical superiority: it must also score on economic grounds. From this aspect, the newer kiln-drying has not always so marked advantages over air-seasoning. The assessment of the economic position is not easy, for not only does this turn on many factors within the process itself, but it is impossible to regard the seasoning operation apart from the whole scheme of manufacture and production of which it is merely a portion. Economically, in one case air-seasoning may be desirable, or in another, air-seasoning combined with kiln-drying or conditioning, while in yet a third kiln-drying timber from the green state may be the best solution.

Finally, mention should be made of an impression, not infrequently encountered, that the research worker, engaged as he is on the work necessary for the technical development of kiln-drying and advocating it strongly as a process which is less widely known than it merits, is striving to substitute it universally for air-seasoning. Perhaps the force of the arguments, which have been necessary in the past to enable the newer

process to gain a foothold, may be responsible for this impression. It should be made very clear that it is without foundation, and that a balanced view of commercial requirements governs the outlook of the Laboratory.

A More Precise View of Seasoning

Timber in normal use is rarely, if ever, found free from moisture. When it is exposed to constant atmospheric conditions, the moisture in it tends to reach, and then remain at, a fixed amount, which depends primarily on those conditions. At this value of moisture content there exists a state of equilibrium between the moisture in the wood and that in the air. If, when the moisture in the wood has become fixed, the equilibrium is disturbed by a variation of the surrounding conditions, its amount will at once begin to change in an endeavour to follow this alteration. Thus, a wooden article, in everyday use, will normally experience constantly changing conditions, and its moisture content will vary in accordance with these, tending in the course of time to lie between limits fixed by the range and frequency of the climatic changes. These variations of moisture content will be accompanied by roughly proportionate changes in dimension, and hence the size of the article, also, will vary between limits. This is, so far as present knowledge goes, inevitable. It will be clear that, the nearer the moisture content of the wood, when manufactured, corresponds to the range which it experiences while in use, the less will the wood change from its original shape. If the moisture content of a wooden article at manufacture lies roughly midway between the limits of the cycle of climatic change, its dimensional change will be least, and its stability will be greatest.

It will be seen that this introduces a conception of seasoning more precise than that of the general reduction of the moisture in wood. It implies the reduction of the moisture, not only to a specified amount, but to an amount suited to the environment of the material in its ultimate use. This precise view of seasoning is an important one. The desirability of such a standard of seasoning is obvious for timber used in cabinet work, decorative woodwork, panelling, parquetting, boot-lasts, shuttles, and other cases where the minimum of movement in the wood during use is desired. But even in other uses, where moisture-movement in the wood is of less importance, it is still desirable to keep in mind the same standard, and to provide that any deviation from it is less than the maximum amount which the particular class of work permits.

The Possibilities of Assisting Industry

Industry realises the need for exact drying, while not always appreciating its real meaning. For instance, the cabinet-maker knows that if too wet wood is used the panels will shrink and split, and joints will gape later, while panels will bulge and distort if they are too dry when made up. It is only occasionally that he can overcome the difficulty by special construction, and he has, therefore, been obliged to develop, by trial and error, more or less indirect methods of attaining a proper state of dryness.

There is no need, however, for such indirect working, since the moisture content requirements for particular uses and environments can be determined by proper and systematic investigation, such as a research laboratory is able to undertake. Moreover, information can be made available, not only regarding the requisite final condition of the wood employed, but also as to the means of attaining it, either by kiln-drying, or air-drying and conditioning.

As regards air-seasoning, although it must remain a crude process, its practice may be improved in many directions. There are certain rules [1], with regard to the construction of the piles of timber and to the state and layout of yards, which have general application, and may be said to constitute good practice. These rules are known to many, but not to the majority of members of the industry. There are also other variable factors, such as the thickness of the piling sticks used, the width of piles, the shape of piles, the spacing and orientation of piles, which, if properly understood and applied in particular cases, would go far to minimise the effect of the lack of control of the drying condition, which constitutes the chief objection to air-drying. These factors are not so well known, and their study can only be carried on by observations made in carefully controlled experiments. In spite of its long practice, reliable data, even on the point of the rate at which air-drying takes place, do not appear to exist. "One year (seasoning) to the inch of thickness" is a common commercial formula, but few would say that oak dries as quickly as Scots pine, or that material five inches thick only needs five times as long to dry to the same extent as one-inch boards.

Without proper data, commercial practice falls between the difficulties of not completing the process or of prolonging it to an unnecessary extent. The periods of time involved in air-seasoning being comparatively long, the latter difficulty is apt to mean an economic loss, the magnitude of which is rarely realised.

It has already been mentioned that air-drying from the point of view of preparing wood for many purposes, notably those concerned with wood used indoors, is an incomplete treatment. For such wood, a further drying is required, which can be carried out in kilns, or if the air-drying has been fairly thoroughly carried out,in simpler forms of apparatus (conditioning rooms) which may be little more than chambers provided with some means of heating and ventilation.

Alternative to air-drying and conditioning is kiln-drying, a speedy and accurate process, which requires, however, skilled operation [2].

Before kilns are actually installed it is necessary to consider the number, size and type required. No one firm can be expected to make trials of several varieties to determine the most suitable. Expense would prohibit it, and at once there is a justification for the institution of research work, not only to examine existing types, but also to endeavour to devise and perfect new ones. After the kilns are installed comes the question of how the timber shall be treated, what instruments and apparatus are necessary to assure the treatment is properly carried out, and the desired result obtained. Again, trial and error would be slow and very costly. After the drying is properly carried out, further care of the timber is still necessary. The moisture content of kiln-dried timber will still change if exposed to unsuitable atmospheric conditions, and it is essential to know how the moisture content can be kept within limits not only up to the point of manufacture, but until the wooden article passes to its appointed place in use. Before proceeding to a detailed account of experiments which have been made or are in progress in the Laboratory, the work of the Seasoning Section will be summarised in the light of what has been written.

Summary of the Functions of the Seasoning Section

Comprehensively, the work of the Section may be said to include the study of all problems connected with the seasoning and conditioning of timber in every aspect—technical, economic, and scientific—with the ultimate object of promoting better utilisation and conservation of our timber resources. Its activities may be divided into experimental work, such as is carried out within the Section itself, the

collection and filing of useful information and data from commercial and other sources, and the giving of assistance and advice to industry. Most of the experimental work of the Section on kiln and air-drying is carried out on a practical scale, and the results can be applied directly to commercial operation. The tests and observations made in connexion with these experiments, though larger in number, are also generally of the type suitable for commercial application.

The general scope of this work includes—

(1) The investigation of the seasoning properties of the timbers more commonly used in manufacture, and the preparation of suitable kiln-drying schedules.
(2) The practical testing of the different general types of drying kiln.
(3) The testing of kiln instruments, and apparatus used in connexion with seasoning.
(4) The study of the effect of varying factors on the air-drying of timbers.
(5) The study of the condition of timber after being put into use.

A part of the experimental work is on a smaller scale, and ovens, which have the essentials of operation of the large drying kilns, are used. The results, while less directly applicable practically, are extremely valuable in a preliminary sense, as they give a reliable indication of the seasoning qualities of a timber, at a small operating cost and with the use of little material.

Laboratory scale work is necessary to calibrate the instruments used, and to determine the degree of accuracy required or attained in the tests made in connexion with seasoning, with a view to their standardization. A small amount of time is also devoted to work bearing on the basic factors which cause and govern the movement of moisture in wood.

Lastly, direct assistance is afforded to industry in answering inquiries regarding problems connected with seasoning and moisture content of timber. Help is also given in the choice of methods, types of kilns, instruments or apparatus to be used for specific purposes. Where a problem is of wide interest, or its solution is of interest from the technical view, special experiments may be carried out in accordance with the general policy of the Laboratory on terms of payment or part-payment depending on certain circumstances of the case.

Work in Progress

The Determination of Appropriate Moisture Content for Furniture Woods

One investigation is concerned with the determination of the most suitable moisture content in timber to be used for definite purposes. At present, this mainly concerns furniture timbers. It was undertaken after consultation with the National Federation of Furniture Trades. Matched and prepared samples of three species of timber are kept in various environments such as in a warmed office, a bedroom, a living room and out-of-doors, in five localities, representing a variety of climatic conditions. The samples are weighed monthly so that changes in their moisture content from time to time can be estimated. Samples have also been prepared to show by comparison with the above, the effect of painting, varnishing and varying thickness on the moisture variations. It is hoped that the data collected will lead to the indication of the optimum moisture content for the timber to be used in different classes of furniture, and generally to show what difficulties are likely to be experienced in the range of environments studied. The piece of work in its present scope has now been proceeding nearly two years, and will shortly be completed.

Kiln-Drying Studies

So far as concerns kiln-drying, the Laboratory has already in use a small scale kiln, used for preliminary work, and four large kilns, each representing a different commercial type. A fifth large kiln, not yet completed, is intended for the study of some of the several different forms of the simple, natural-draught kiln, which are found in commercial use. The primary use of the large kilns at present is the collection of data connected with the seasoning of different species. While observations on the behaviour of the kilns themselves are secondary, nevertheless opportunity is afforded of acquiring much useful information.

Kiln Design

Measurements of circulation, temperature distribution, and the effect of minor modifications in methods of piling can be observed during the kiln experiments and conclusions drawn from them. For example, Fig. 2 demonstrates the advantage of a kiln in which the circulation is produced by a fan, over that with a more sluggish air-movement caused by water-sprays. In the fan kiln, the boards on the side of the pile by which the air enters are dried to 15 per cent. moisture content in seven days, while on the other side, this content is not reached until a further period of two and a half days has elapsed, representing an addition of 36 per cent. on the first time. In the other kiln, the additional time required is 6¼ days in excess of the 8¾ days required for the inlet boards, or 72 per cent. It should be noted that, so far as concerns the inlet side boards, there is little difference in the rate of drying in the two kilns. What difference exists may be accounted for by the lower temperature used in the water spray test, the higher initial humidity and moisture content of the wood. It is on the opposite side of the pile that the greatest difference is found. After all, however, the whole pile must be dried, and, therefore, the longer period occupied by the slower drying portions represents the time required for the complete operation. This slower drying, due to the greater lag of one side of the pile as compared with the other, is typical of kilns with a slow circulation. It is less pronounced when the species dries less freely, and particularly when timber which has already been partly seasoned (e.g., many imported varieties) is being dried. In certain cases the disadvantage in drying rate may thus be reduced so as to be amply compensated by the greater cheapness and simplicity of a kiln not provided with the fan necessary for the more rapid air movement.

By observations of this type, information is acquired as to the suitability or limitations of the various types of kilns for different purposes.

The method of actually working the kilns in the experiment is commercial in character, except that the observations made are generally more numerous than would be expected in industrial practice. Study of the variations in these numerous observations, however, gives the best indication of the possibility of limiting their number in commercial work and of laying down the simplest practical routine of operation and testing.

Instruments and Apparatus.—Investigations are by no means confined to the kilns themselves. They embrace also instruments for measuring and controlling the important factors in kiln operation (viz., temperature and humidity), apparatus for determining moisture content, and for making other necessary observations connected with the drying operation. It may be said that not only is the instrument regarded from the point of view of its scientific accuracy, but the question of its robustness and general suitability as a commercial instrument is also considered, as is the economical aspect, in the sense of what service it gives in relation to its cost.

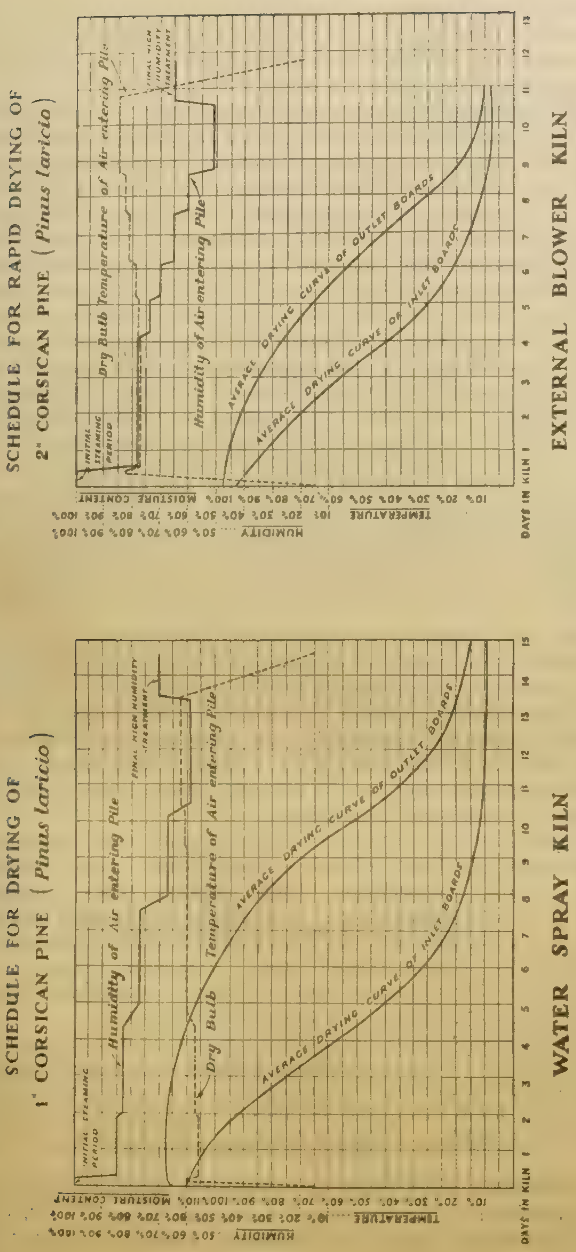


FIG. 2.—Comparison of the rates of drying of Corsican pine in kilns with slow and rapid circulations respectively.

The Seasoning of the Species of Timber.—In the experiments on kiln-drying, so far as its effect on the different species is concerned, the object is to determine schedules by which the timber can be dried to suit the purpose for which it is to be used in manufacture or service.

The range of conditions to which each timber can be safely submitted must be investigated. The factors involved in this aspect of the problem are those of temperature and humidity of the air in relation to moisture content of the wood, and to a less extent the circulation of the air. With these factors is bound up, also, the duration of treatment. It will be noted that the problem is not solely to discover one treatment, but to discover the effects of a variety of treatments. In woods used for aeroplane construction it is essential that the material should have its maximum strength. A kiln-drying treatment for such woods must be such as to ensure no deterioration of their mechanical properties. On the other hand, for furniture woods, appearance is of greater importance than strength, and provided that a good external surface remains, the drying may be accelerated at the expense of the mechanical properties. It will be seen that mechanical and wood-working tests of the kiln-dried material for each type of treatment are desirable, and these are arranged for in the Laboratory.

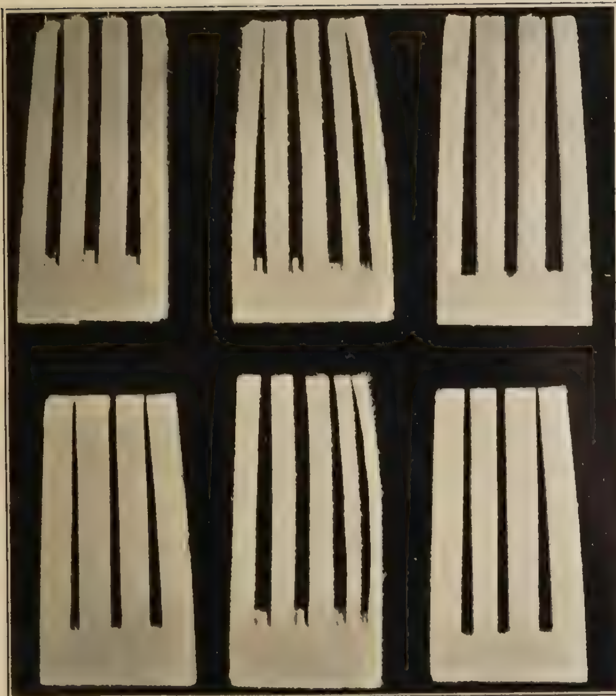
The general method of carrying out the kiln-drying experiments is basically by trial and error. The general form of the schedule is known, and for the first experiment it is necessary to choose only an initial temperature and humidity condition reasonably suitable to the species under test. This can generally be done from knowledge of the species, from inferences drawn from comparison with other species, the seasoning properties of which are known, or from preliminary small scale tests. The results of the first experiment indicate the lines on which a second or third experiment may be made.

In order that the results of an experiment may be properly assessed, and that the effects of different treatments of a species may be compared, a system of grading the timber before and after experiments has been developed. This takes cognisance, in a concise yet comprehensive manner, of all defects which may have been caused or aggravated by the seasoning treatment. In view of the existence of commercial grading systems, by which the quality of timber is expressed, it should be stated that the experimental grading used for the kiln experiment is not of the commercial type, nor has it any direct commercial significance.

In order to limit the large number of experiments, the kiln-drying investigations into different species is restricted, except in special cases, to one thickness of material, viz., two inches. A full investigation would involve other thicknesses and these frequently need to be considered later. The results of the tests on two-inch material, however, can be used as a basis on which to estimate fairly accurately what would be the behaviour of one to three-inch thick stock ; and it is, therefore, considered more expedient to investigate the commoner species as soon as possible, rather than consider a more limited number only, even if in a more complete manner.

The present scheme of work is confined to the testing of home-grown, or where the demand for such species in home industry warrants it, Empire-grown timbers. At present the following species are under investigation or intended for early consideration : Scots pine, European larch, Douglas fir, beech, ash, oak, elm, while others will be taken up as soon as possible. Tests on Corsican pine have been completed for the present.

The above constitutes what might be termed the general project in kiln-seasoning work. Special experiments, having some particular object in view, are frequently carried out, and a description of some of them will best indicate their type.



Sitka Spruce Air-seasoned to 25 per cent. moisture content.

Sitka Spruce after subsequent Kiln seasoning to 12 per cent. moisture content.

FIG. 3. Casehardening test samples showing that stresses, set up during air seasoning, can be relieved by proper treatment during subsequent kiln-drying.

Facing p. 31.

Special Experiments in Kiln-Drying

The Seasoning of Oak for Wheel Spokes.—Occasioned by the War, there arose a question of the possibility of drying oak in three-inch thickness for use in artillery wheel spokes. It was found that kiln-dried spokes were frequently brittle. Experiments were made involving several drying treatments which appeared to indicate that brittleness could be eliminated by drying the oak sufficiently slowly.

The Seasoning of Aircraft Quality Sitka Spruce.—The question as to the possibilities of kiln-drying aircraft spruce without reducing its strength is an important one. In this country the timber is normally air-dried. A load of spruce already air-seasoned to 25 per cent. was dried carefully in a kiln to 13 per cent. moisture content. In appearance the resulting product was most satisfactory, and when tested for strength was found fully up to standard and was passed for service. The photograph reproduced in Fig. 3 shows the casehardening stresses which existed in the spruce through air-seasoning, before the kiln-seasoning test was made. These stresses, although they were not of a permanent nature since they were removed in the kiln-seasoning, were quite severe and comparable with the stresses set up in many kiln-drying operations.

Ash for Vehicle Construction.—A similar enquiry, involving the question of strength deterioration during kiln-seasoning, was raised as regards ash, with special reference to vehicle construction. Not only was the deterioration suggested to result from kiln-drying, but also to occur in kiln-dried timber during storage subsequent to drying. Strength tests on experimental kiln-dried material revealed that the mechanical properties were not impaired during drying, and further tests since have shown that no deterioration has resulted after one year's storage. Some of the material is being kept for further tests at a later period.

Panelling for Railway Coaches.—The kiln-seasoning of teak and mahogany panelling for railway carriage work has been carried out with satisfactory results.

Large-Sectioned Material with Central Hole.—Another investigation of some interest concerns the kiln-drying of large-sectioned round material bored with an axial hole. Some maple rollers 8-in. in diameter, with a 2-in. hole, were piled in a kiln so as to ensure that the air circulation passed not only along their outer periphery, but also through the central hole. It was thought that from this arrangement the rollers would dry approximately at the rate of flat stock of the same thickness as the difference between the radii of the roller and the hole, i.e., as 3-in. stock. This proved to be the case, and local moisture determinations made at various times during the test on the outer surface and on the surface in the hole, confirmed that the drying at two faces was not very different.

Sterilization against Fungus and Insect.—It may be added that experiments have already been made to test the efficacy of certain kiln conditions in sterilizing wood infested with fungus and insect. In both cases successful results have been obtained, and in the latter case, which concerns the *Lyctus* beetle, further work is being carried out in conjunction with the work on Entomology (see page 55), which, it is thought, may show that in many cases a special lethal treatment is not necessary, but that the normal kiln-drying process is sufficient in itself to destroy the insect.

Special Air-Drying Tests

Rapid Drying of Scots and Corsican Pine.—Special studies in air-drying are already being carried out. For instance, a pile of Corsican pine and Scots pine boards were

dried rapidly during the summer months, to compare their seasoning qualities under such conditions, with their behaviour in the kiln. The main object of the investigation was the study of the effect of the different modes of seasoning, although figures relating to the drying rates of the timber also resulted.

Pitprops.—Work has also been carried out on the seasoning of pitprops, under various siting and piling conditions. This, together with the collection of data as to the moisture content of props actually used in mines, forms part of a general investigation by the Laboratory, the object of which is to assist in the extension of the use of home-grown timber in the mining industry.

British Oak.—Experiments are being made, again as part of a general Laboratory investigation, into the air-seasoning of British oak grown under different soil and climatic conditions. Inquiry from experienced timber-users revealed a variety of opinion as to how oak should be air-seasoned, one user advocating immediate conversion and piling with sticks, another conversion with close piling for a period, while others suggested various periods of seasoning in the log before conversion. It appeared that there might be merit in all these proposals, particularly if considered in relation to some particular quality of the oak due to its condition of growth. The matter is of considerable importance, particularly as the kiln-drying of oak is not an easy matter, and accordingly groups of oak from different localities were collected and submitted to air-seasoning under the methods proposed, including, also, storage of logs under water for one year. These tests are still proceeding.

Common Elm.—Lastly, so far as air-seasoning is concerned, hedge-grown common elm, which, when dried in a kiln, deteriorated through abnormal warping and shrinkage, is being dried to discover if these defects occur in drying at normal temperatures. Some of the elm has been piled in stick in normal fashion, and some without sticks. A further amount is being water-soaked for a period of six months prior to drying, while four trees will be girdled (a practice known to be efficacious in the case of some tropical species), to see whether the wood, having dried to some extent while standing, is finally less liable to distortion.

The Warping and Cupping of Timber

Among problems connected with seasoning may be mentioned that of the warping and cupping of sawn boards. Boards may be made to warp and cup by defective seasoning methods, such as drying a portion or the whole of one face more quickly than the rest. Such distortion may be said to be directly caused by the manner of drying. Warping may, however, also occur under perfect drying conditions, due to uneven shrinkage in a board in which the grain is irregular. Cupping also occurs in a through-and-through-sawn board, due to the greater shrinkage which is natural in the direction of the rings, as compared with that at right angles. Distortions from these causes, though not entirely so, are largely independent of the manner of drying. They cannot strictly be classed as drying defects, and though they only occur as the drying proceeds, they are really features of the manner of growth or of the conversion of the log.

It is commonly believed that warping and cupping can be reduced by pressures such as are afforded by the placing of steel rails or light girders on a pile. This is true to some extent, and observations tend to show that boards placed at the bottom of a pile are less distorted than those above, due to the weight of those above them. It is found, however, that as might be expected in the case of such restraint of natural

tendencies, the reduction of the board's movement is accompanied by an increase in splitting and checking.

(1) OLIPHANT, F. M. The Air Seasoning and Conditioning of Timber. *Forest Products Research Special Report No.* 1. H.M. Stationery Office, London. Price 2*s*. 0*d*. net.
(2) STILLWELL, S. T. C. The Principles of Kiln Seasoning of Timber, Part II. *Forest Products Research Special Report No.* 2. H.M. Stationery Office, London. Price 9*d*. net.

TIMBER MECHANICS

Introduction

A knowledge of the strength of timber is required whenever timber is to be used in a structure or employed in some service where strength is a factor in the design. This knowledge is essential for the economical design of wooden members or parts subjected to stress. If it is lacking, proper proportioning cannot be obtained nor can the risk of failure under working loads be reduced to a minimum.

Since timber is a natural product, its characteristics are not controlled during a process of manufacture. It is true that the conditions under which the timber is grown can be controlled to some extent by the foresters, especially in afforested areas, but in general the characteristics of the timber of any species will vary within wide limits in density, rate of growth, proportion of summerwood, structural arrangement, and other characteristics. Further, timber when freshly felled contains a large quantity of water, which, although diminished by seasoning, is never completely evaporated, but is always present in sufficient quantities to be a very important factor in the strength.

Experience has shown that, within any one given species, the variations of the different characteristics will cause variations in the strength of the timber. It has been found, for instance, as would be expected, that the strength of a timber increases with its density. Experiments have shown that the strength of timber will depend on the rate at which the tree is grown ; also that there will be an optimum rate of growth for any given species, and perhaps for the species in a given locality.

In general, it has been found that the softwoods or conifers yield stronger timber when grown comparatively slowly, while in the case of ring-porous hardwoods, such as ash, the best mechanical strength may be expected from trees that are grown quickly.

Tests on specimens of timber of similar characteristics, but with variable moisture contents, indicate that as the timber dries the strength remains constant until a critical point is reached, after which the strength increases very rapidly with any further reduction of moisture content. The point at which this change in behaviour takes place has been shown to correspond with the condition in the timber in which the evaporation of the free moisture from the cells and cavities is completed, and the moisture that remains is in the cell walls themselves. As already stated (see page 20), this point has been termed the "fibre saturation point," and it is always important to know, when dealing with the strength of timber, whether the state of seasoning is above or below this point.

If the same test is applied to two samples of timber cut from the same species, there is likely to be observed a considerable difference between the results, especially if the samples have not been carefully matched in their structural characteristics and moisture content. Owing to the wide variation that is to be expected in the strength of a timber of a single species, it would be impossible to estimate the probable strength of a timber member if the influence of each of the factors which influence the strength were not independently determined. The moisture factor can be allowed for by

controlling the conditions of seasoning, and by carefully weighing the specimens to assure a uniform moisture content at the time of test ; but the variations in the natural characteristics, such as rate of growth and density, can only be estimated after a careful comparison of the results of a great number of tests. In this way it is possible to isolate each of the variables and so determine its influence.

Some assistance can be rendered to foresters in future plantings through the results of tests which show the optimum rate of growth for a species to produce the best mechanical timber. From this information the foresters can estimate, in conjunction with their growth tables for any given district, the spacing of trees which should produce the desired radial growth of the trunk in each year. The comparative tests of the same species of timber cut in different parts of the country also indicate to the forester the areas or districts in which the species may be expected to grow to the best advantage and at the same time will indicate in any given district the species which are likely to prove of the most economic value.

In economic practice, the timber that is employed for any given purpose is usually first determined by a method of trial and error, until the most suitable or the cheapest timber is found. The use of this timber is then continued until the question of supply and demand enters and it is thought necessary to seek elsewhere for suitable replacements or substitutes. Modern timber testing for the comparative values of the different species of timber yields results that serve to indicate those timbers which are of a similar mechanical nature to those already employed, and may perhaps indicate timbers that would be more economical for the purpose. Of course, in many cases it is necessary to put the timber into actual practice to confirm the results of the laboratory tests.

In the past the practice has been to test full-size members to destruction, and from the results of these tests to compute the proportions and quantities of a timber structure. Experience showed that in such methods it was necessary to employ very large factors of safety, which in turn entailed an extravagant use of timber. Modern methods, however, tend towards the evaluation of the defects to be found in structural sizes of timber, and the development of a system of grading to limit the allowable sizes of defects and enable a close calculation to be made of the true strength, with consequent reduction of the necessary factor of safety and hence economy of material.

There are many services in which wood is employed where the absolute strength of the timber is thought to be an important factor, and yet where analysis would show that the actual strength and mechanical characteristics are really of no great significance. The one striking exception to this is the design of aircraft, where the true engineering quantities are required in order to calculate the strength of the structure and to estimate the shape and disposition of the various parts when the structure is under strain. But in most cases the employment of timber in a mechanical way depends not so much on the absolute strength of the timber as upon the comparison of its strength with that of other species.

Timber-testing in Europe may be said to have been begun approximately 200 years ago, while in America research in this direction was begun in Government and private laboratories in the United States about 1875, and was carried forward in that country under the Forest Service.

It was early acknowledged that there should be timber tests of three kinds :—

1. Tests of material free from defects, such as knots or cross-grain, to determine the relation between physical and mechanical properties and to form a basis of a general comparison of species.

2. Tests on structural or large-size timbers, and of small clear specimens* cut from them, to determine the influence of defects upon the strength and to provide data for use in design.
3. Tests of wooden parts of a mechanical character, such as, for example, tool handles and vehicle parts.

It was originally thought that the first group of tests could be satisfied by comparatively few specimens of each species, that the relation between the properties of a species could be defined through these tests, and that probably the relation between different species would not require anything more; but it was soon proved that the variations which occur in the timber cut from one species, or even from one tree, are so great that a large number of tests of each species are required in order to give a satisfactory average.

A definite beginning of systematic testing of timber with a view to the comparison of species and the determination of physical and mechanical properties was made in the United States about 1902, when Dr. Hermann von Schrenk, of the Forest Products Division of the Forest Service, and Mr. W. K. Hatt, in charge of Timber Testing, formulated a plan which was placed before the International Association for Testing Materials and the principal engineering societies of the United States. This plan led in time to the work which was undertaken at the Forest Products Laboratory at Madison, where it was centralized in 1910. The testing of clear timber specimens has been accepted as a basis of the comparison of species of timber throughout the world. The system of tests was adopted at the Canadian Laboratory at Montreal in 1913, at the Forest Research Institute, India, in 1920, and subsequently in New Zealand, South Africa, and the Federated Malay States. An outline of the method as adopted at the Forest Products Research Laboratory is given in Project 1 [1].

Principles of Testing

The variations in the inherent characteristics of a species of timber render the testing of timber for any one property exceedingly difficult. It is found in practice, even in specimens that have been cut adjacent to one another (either side by side or end to end), that the properties will sometimes vary sufficiently to upset the normal expected trend. However, since it is only by getting closely matched specimens that we can hope to eliminate and evaluate these variables, it has been found necessary to take these specimens in a systematic way—matching them (1) radially, i.e., in a direction from the heart of the tree towards the bark, (2) tangentially, or at the same distance side by side from the heart of the tree, and (3) end to end. This method of side-matching and end-matching samples is adhered to in all testing of small clear specimens whenever the influence upon strength of some process, such as seasoning or creosoting, is to be investigated. By means of these matched samples, of which one from each pair is tested when treated and the other—the control sample—is tested when untreated, it is possible to determine the effect of the process in question.

Owing to its structure timber is a difficult material to test, for not only must consideration be given to the direction of grain of the specimen, but also to the relation of its radial and tangential characteristics, and in many tests duplicate specimens must be tested to provide for the different properties encountered in these two directions.

Although greater importance is attached to the tests of large size specimens when the results are to be employed in the design of timber structures, yet for many purposes, and particularly for the selection of suitable timbers for a specific service,

* Compare p. 7 para. 24.

tests on small clear specimens of timber yield very useful results. It has been found, after comparing the data obtained from the tests of large specimens, that similar defects influence the strength of timbers in much the same way irrespective of the species. This result is of considerable importance in that it makes possible the assessment of the influence upon strength of a defect of a certain dimension. For example, the strength factor involved in a knot 2 in. in diameter would be the same, provided the other characteristics were identical for all species. Similar conditions have been found to hold for other defects, such as diagonal grain, checks, splits and so forth. It has, therefore, become evident that exhaustive and expensive tests on large size specimens are not always necessary except where the smaller scale test showed a tendency of the species to depart from the general rule. In such cases it is necessary to carry out sufficient tests to obtain the appropriate factor for the particular species.

The system of tests for small clear specimens of timber was developed with the object not only of comparing one species with another, but also of studying the effects of physical characteristics on timbers of the same species. The method of obtaining material and of allocating material to the different tests has been so arranged that very concise data are attached to each specimen tested. Thus the technologist or timber physicist has at his command for microscopic examination and analysis material of which the complete history is known—habitat, position in the tree, conditions of growth, methods of conversion, seasoning and testing. The trees are selected standing in the forest, and as a rule only those are chosen which will yield timber of commercial dimensions. The trees must be carefully identified by a forester or botanist so that no doubt will arise as to the strict identity of the species when it is tested.

The mechanical tests adopted are, as explained, similar in all respects to the tests of the same kind used at various laboratories throughout the Empire and in the United States of America. That similar methods should be employed is of the utmost importance in order to procure figures representing the mechanical and physical properties from the several laboratories, which provide a direct comparison of the species of timber, and so obviate the necessity for repeating the tests on the same species. By adopting the same procedure of tests, the properties of the timbers tested at this Laboratory can be compared directly with the results of upwards of 2,000,000 tests performed at other laboratories.

The background of testing which has been established over the last quarter century serves the very useful purpose of assisting in the introduction of new species of timber, for enough experience has been gained to show how far the indications of mechanical properties obtained from the tests of a new timber may be taken to represent the actual value of the timber in service.

Description of Tests

The procedure followed in the collection, preparation and testing of timber may be summarised as follows :—

Identification of five or more trees of the same species in the same district.
Noting the conditions of growth and surroundings.
Marking each tree before felling with reference to the true North to allow for the correct orientation of the specimens cut from the log.
Felling the trees. Extraction and transportation to the Laboratory.
Conversion of the logs into sticks.

Allocation of the sawn sticks into two groups which are both side matched and end matched; one group for testing immediately as received, the other group to be seasoned until the moisture content has reached the standard degree of 12 per cent.

Allocation of the material in the group to be tested to the requirements of the eight mechanical tests.

Preparation of the testpieces from the sticks, preparation of shrinkage specimens.

Mechanical tests.
- Static Bending.
- Impact Bending.
- Compression Parallel to Grain.
- Compression Perpendicular to Grain.
- Hardness.
- Shear.
- Tension Perpendicular to Grain.
- Cleavage.

Physical Tests.
- Radial Shrinkage.
- Tangential Shrinkage.
- Volumetric Shrinkage.

Characteristics.
- Rate of Growth.
- Percentage Summerwood.
- Density.
- Weight per cubic foot.

Computation of Results.

Summaries.

The static bending test employed for the small clear specimens entails loading the specimen at the centre and supporting the ends in almost frictionless chairs. The results obtained from this test are affected to some degree by the longitudinal shearing strength of the timber, but this in no way affects the usefulness of the test in the field in which it is employed. On the other hand, it allows the selection of a testpiece with greater freedom, as the critical portion at which the fracture is likely to take place is confined to the middle of the span, and in species where defects occur at frequent intervals, specimens for this test may be cut where it would be impossible to obtain a sufficiently clear specimen over a long length for test under a uniform bending moment.

The impact test uses a specimen exactly similar to the one employed in static bending, and the ends are again supported while an impact load is applied at the centre. This test is carried out by applying successive increasing blows at the centre of the specimen by a falling hammer or tup, while at the same time an autographic record is obtained which indicates the deflection produced by the blow and the behaviour of the testpiece under each successive blow. This record is continued until the weight has been raised to a sufficient height to cause a blow which will strain the material past the limit of proportionality of stress. The record is then discontinued, but the test proceeds, still by increasing the height of the drop of the hammer, until complete failure of the specimen has been obtained. This method of testing under impact is the only one which produces a record of the behaviour of the specimen within the elastic limit.

Many attempts have been made to produce a satisfactory, yet simple, testpiece for compression parallel to grain, but none has proved entirely satisfactory. The simple

prism 8 in. long with a 2 in. by 2 in. section has been retained as the standard testpiece, in which a gauge length of 6 in. is employed for the compressometer. The chief objection to the testpiece of this shape is that, when in contact with the metal platens of the testing machine and under stress, there is an abnormal concentration of stress at the edges of the square ends. This results in the fraying or crumbling of these edges, and frequently in failure taking place at the ends of the testpiece. The work of Professor E. G. Coker, of University College, London, on the distribution of stress in elastic material has led to the introduction of a conical frustum, between each end of the testpiece and the machine platen. These are made of wood of a similar nature to that being tested, preferably of the same species, but slightly denser or drier, in order to ensure failure taking place in the testpiece rather than a resultant crushing of the frustum itself. The frustum is of the same size as the end of the testpiece, but is $\frac{1}{2}$ in. larger on each side at the base, where it comes in contact with the testing machine face. This increase to $2\frac{1}{2}$ in. at the base maintains the same ratio of 4 to 1 for length to side of specimen. Some very satisfactory results have been obtained through this innovation.

The test for compression perpendicular to grain is made on the edge grain or radial surface of a testpiece over an area 2 in. by 2 in. This test is in the nature of a hardness test, and is only carried through to a point where the pressure plate is embedded in the wood to a depth of 1/10th of an inch. A curve is drawn for this test, in which is plotted the load on the depth of penetration of the plate. An elastic curve is obtained and the graph continues past the limit of proportionality. The usefulness of this test is to indicate those timbers which are suitable for such articles as rollers, wedges, etc.

The hardness test is that developed by Professor Gabriel Janka. A sphere having a projected area of 1 square centimetre is embedded in the wood to half its diameter, and the measure of hardness is the load required to produce this condition. This hardness test has been universally adopted as the standard test, and it has been found very useful as an indication of the resistance of timber to the indentation and breaking up of its surface by the application of concentrated loads over small areas, as, for example, the indentation of flooring through human and other traffic.

The shear test is applied to timber in each of two planes parallel to the grain. The testpieces are carefully cut so that the plane of shear is alternately radial or tangential with reference to the growth rings of the tree. This test, although it does not develop a pure shearing stress, yet produces a measure of the tendency of timber to fail under shear, and is found to be quite useful in the relative comparison of timbers.

It has been felt for some time that the attachment used in connexion with this test has permitted a considerable frictional load to be included as part of the apparent shear strength of the timber. A new attachment has been designed by the Laboratory in co-operation with the Royal Aircraft Establishment and is now in the course of manufacture. This new design introduces roller-bearing slides to reduce the friction at those points, and also a modification in the method of holding the specimen whereby a lateral reaction, which has hitherto been taken by the sliding plate with a corresponding increase of frictional error, is now taken by a small bar, which is part of the stationary base. This will necessitate a slight modification in the shape of the testpiece, but will in no way increase the difficulties in its manufacture.

The failure of timber through splitting or cracking when nailed or bolted together has been simulated in the tests designed for cleavage and tension perpendicular to grain. In the first of these tests the wood is split or torn apart along the grain from one end of a notched specimen. The results of this test, combined with the figures

obtained from the hardness test, assist in the choosing of timber which is not likely to split when being nailed; while in the test of tension perpendicular to grain, the comparative strength of the timber to resist splitting between bolt or other fastenings is indicated. In both of these tests it is necessary to adhere to the exact form of testpiece specified, as the apparent strength developed is a function of the shape of the testpiece.

The development of structural Tests

The testing of timber in structural sizes may be developed in either of two directions. The direction which is, apparently, upon first thoughts, the most useful one to pursue, is that of testing a large number of these large-size specimens with a view to determining the strength of such a member as would be used in timber construction. However upon further consideration it becomes evident that, should this course be pursued, the cost of the investigation would be excessive, and the results obtained would be of uncertain value. The chief difficulty in testing structural timber is the assessment of the true value of the influence of the defects, and it is found that the more satisfactory manner in which to approach the problem is to test for the influence of the defect, and so by a series of tests, to form a catalogue of the defects and their influences as factors affecting the strength of the timber in which they occur. When once the significance of this method of testing structural timbers is appreciated, it will be seen that a considerable economy in the investigations upon the strength of timbers will be effected, and that once the values of the defects have been assessed, it becomes possible to compute the probable strength of a timber within reasonable limits of accuracy. Moreover, when once the catalogue of the defects for a species with their influences upon strength has been made, no further testing of the same species is required unless it becomes evident that a different sylvicultural treatment, or some other factor, has caused later supplies of the timber to assume characteristics differing from those of the same species previously tested.

As already explained, it has been found a practical possibility to allot factors to the various defects and characteristics of timber, and so to calculate the probable strength of a timber of any dimensions by the application of these factors to a figure representing the strength of a piece of timber of the same species and dimensions which was not affected by the presence of defects.

Following upon the introduction of the factor system in calculating the strength of timbers must necessarily come a system of grading timber which will limit the defects in certain classes of timber. When once the allowable defects in a class of timber have been standardised, the corresponding safe working stress may be readily allotted. It becomes then a comparatively simple matter to deal with the many species of timber with reference to their grades, as falling into definite classes according to their safe working stresses.

It is also a practice to introduce a factor representing the modification in safe working stress to be made on account of the exposure of the timber to rain, or other moisture. Three conditions of exposure have been arbitrarily assumed—(*a*) continuously wet, (*b*) occasionally wet, but quickly dried, and (*c*) continuously dry. Here, again, the method of factors from a practical standpoint is quite simple.

Testing for variation in design

It has already been said that the distribution of stress in timber is difficult to compute, and this is especially so when the section of a timber member departs

from the simpler geometric forms. In cases where it is necessary to have a peculiar section for a timber member it is the usual practice to shape timber specimens to the form desired, and to compare these under test with similar members of other shapes, and so to determine the most efficient cross section for the member in question.

The method of testing manufactured parts is also of use when finally selecting the most suitable species of timber for a particular service. One example of such testing carried out in the Laboratory was in the matter of a possible substitute for American hickory for shunting poles for the railways. From the tests of small clear specimens of timber it was possible to select several species which, seemed likely to answer the purpose: poles were shaped from material of these species and the specimen poles were then subjected to a direct comparative test. This test showed that Burmese yón (*Anogeissus acuminata*) was just as strong as and somewhat stiffer than, hickory, and the results of the tests have been acted upon by the Railway Company concerned, who have put a number of such poles of this timber into service for practical test.

Acceptance or proof tests

Testing a few samples of timber, and using the results as an indication of the general strength has been the usual trade practice for timber as for other materials. This testing has been done without reference to the matching of the general characteristics of the timber. It has been frequently proved that the testing of samples taken at random, without reference to grade, is likely to lead to erroneous conclusions, and may result either in the acceptance of poor material or the rejection of good material. An appreciation of the influence of the characteristics of the timber is a much surer guide to the selection of material of the desired quality than is the testing of a few random samples from the general supply.

Work in Progress

Tests of small clear specimens

The comparison of species is one of the fundamental objects of timber-testing, and this has been carried out through the testing of the small clear specimens already referred to. Testing machines, of suitable design for this work, were purchased and installed early in 1926 at Farnborough. Since then the routine testing on this investigation has proceeded except for that period during which the Laboratory was being removed to the new buildings at Princes Risborough. Some of the results of these tests on home-grown timbers in the green condition have been published as Project 1, Progress Report 1 [(2)]. Five species are there dealt with, namely, ash, Douglas fir, European larch, Corsican pine and Scots pine. Further tests on green material have been carried out on pedunculate oak, two consignments of common elm, Dutch elm, beech, and on a second consignment in the cases of Corsican pine, Scots pine, Douglas fir, and European larch. Material that had been set aside to season from the first consignments of Scots pine, Douglas fir, European larch, Corsican pine and ash have since reached the desired degree of seasoning corresponding to a moisture content of 12 per cent. and have been tested.

The logs upon arrival at the Laboratory are sawn into suitable sticks from which testpieces may be made. These sticks are cut in the log saw to a square section of about 2¼ in. by 2¼ in. and 4 ft. in length. The whole log is not converted into such sticks, but only that portion which extends in the form of a cross laid on the cardinal points of the compass with the centre at the pith of the tree. The lay-out for this material is easily accomplished through the use of a stencil applied to the ends of the

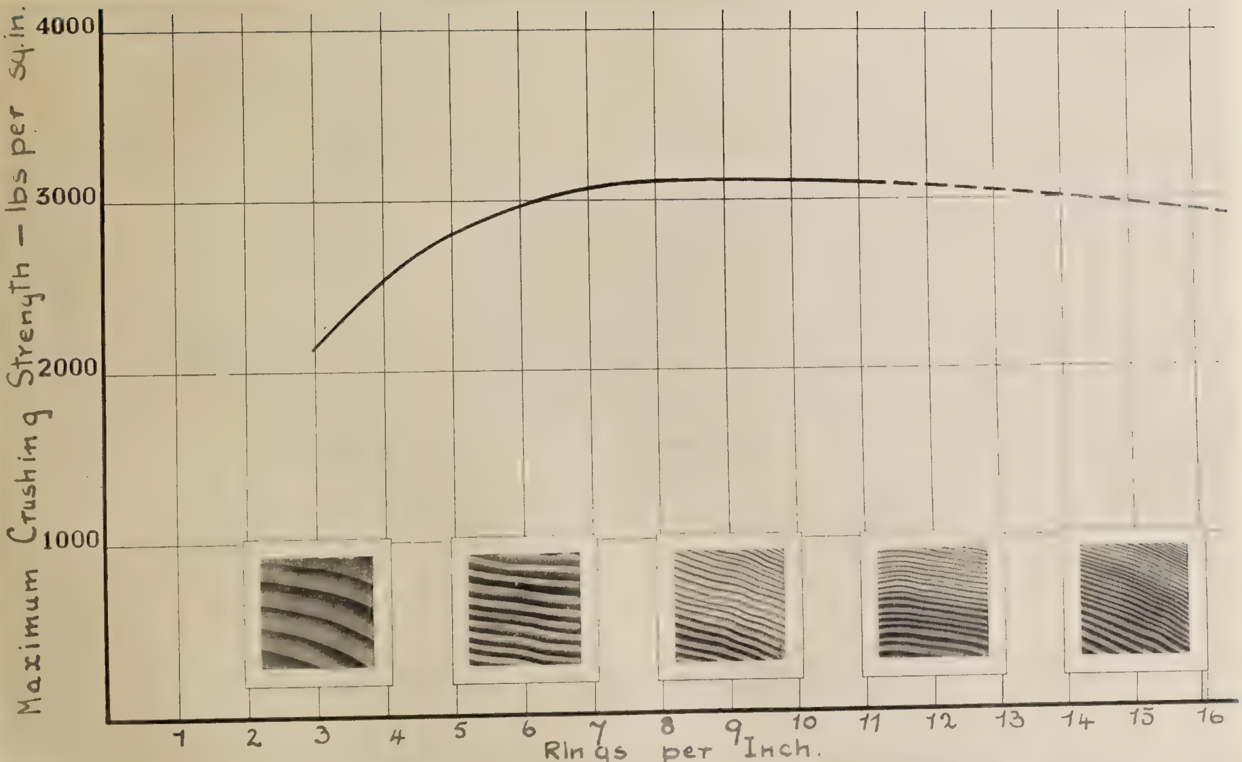


FIG. 4.—Crushing strength of Douglas fir with relation to rate of growth.

log. The log when placed on the saw carriage is aligned with reference to this stencil, with the result that the sticks are sawn from end to end of the log, along the lines laid out by the stencil, and, as far as the straightness of the tree will permit, parallel to the pith. Suitable symbols are used to denote the position of each stick as it occurs in the log, and these symbols are transferred to each specimen that is cut from any of the sticks, so that when a testpiece comes to the testing machine it bears a system of symbols which readily identify the material of the testpiece with the tree from which it was cut, and also its exact position in the tree within reasonable limits.

This systematic conversion of material makes the results of utmost value to the wood technologist. He may have at his disposal as many as a thousand samples cut from perhaps five or more trees of a species of one distinct locality, and not only will each one of the discs have attached to it a description of the mechanical and physical properties of the specimen from which it was cut, but also the history of the tree and the relative position of the material in the tree. This places before him information of the utmost value regarding the relation of wood structure to strength.

Work on the testing of small clear specimens of timber is progressing vigorously, and during the last twelve months over 20,000 mechanical and physical tests have been carried out. The results of these tests are in various stages of computation, some of them finished and summarized, and these will, as opportunity affords, be published in the form of progress reports similar to *Progress Report* 1.

Influence of rate of growth. Douglas fir

One investigation which is concerned to some extent with the relation of the structure of timber to its strength, has been carried out during the past year. This investigation has correlated the compressive strength of home-grown Douglas fir with its rate of growth. From the curve given in Fig. 4 it will be seen that Douglas fir, used as a post supporting a load, may be expected to have its best mechanical strength when the timber has been grown with between 7 to 11 rings to the inch. Timber grown quicker than at the rate represented by 6 rings to the inch has poor mechanical properties, and cannot be depended upon to resist any great strain. This information should be of value to foresters in this country when planting and tending plantations of this species.

Influence of the position in the tree

As a result of a question raised by manufacturers of sporting goods as to what part of the tree would yield the most efficient mechanical timber as measured by the ratio of strength to weight, an investigation was carried out on a consignment of ash collected in the Forest of Dean, with the object of determining how strength of ash in bending varies with its density. In the investigation the regular routine tests were followed, the results were regrouped so as to relate the static bending strength to the density of the timber and its height in the tree. The specimen trees as collected were divided into short logs, each 4 ft. in length as measured from the stump upwards along the trunk. Nine trees in all of this species were taken, and the results of all nine trees were plotted to show the strength in static bending of each specimen on a density base (Fig. 5). One curve is obtained for the specimens taken from the first 4 ft. log above the stump of each of the nine trees. A second curve was obtained for the second 4 ft. log, that is, the timber between the heights of 4 and 8 ft. from the stump, and again for each of the two succeeding 4 ft. logs, while a combined curve was taken for those portions of the tree between 16 and 28 ft. from the stump.

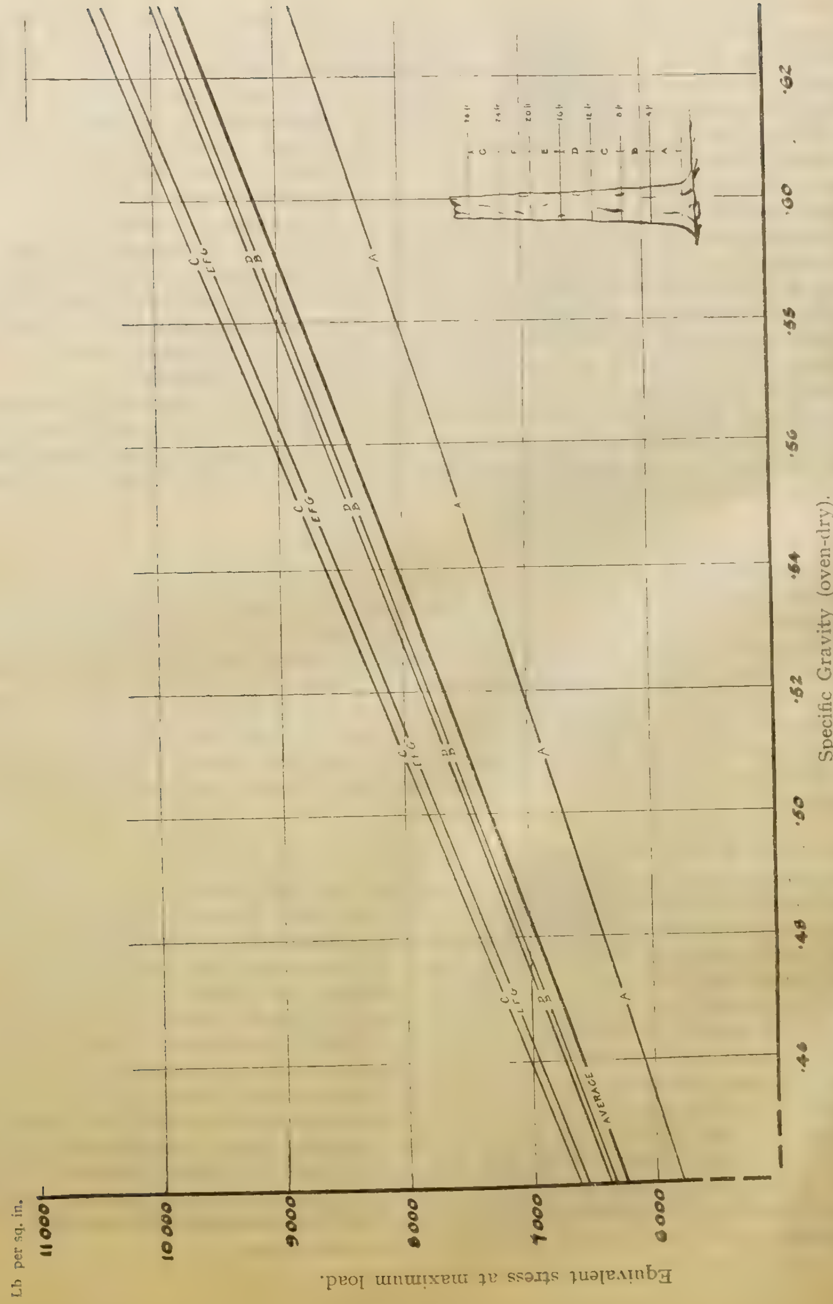


FIG. 5.—Influence of position in the tree upon the relations between bending strength and density of ash.

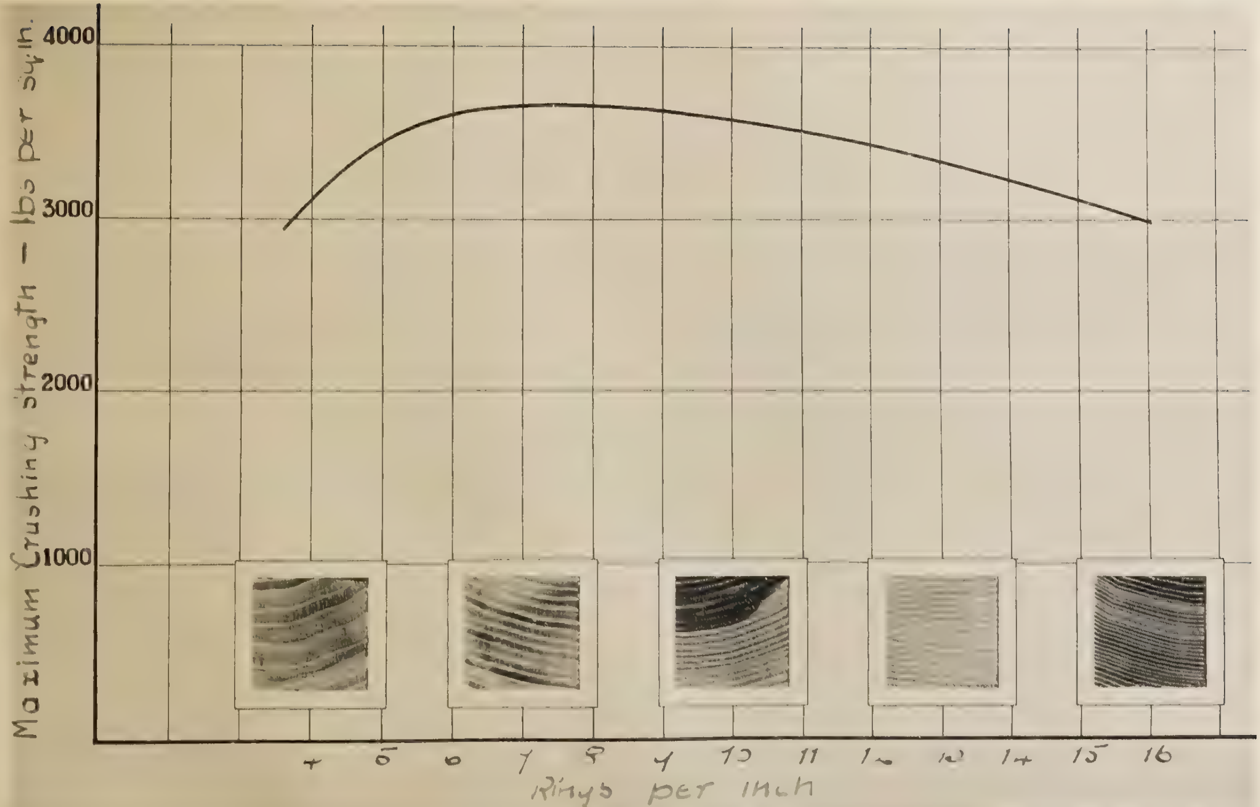


FIG. 6.—Crushing strength of ash with relation to rate of growth.

The results of this investigation show that the best combination of static bending strength and lightness is to be obtained from timber from that portion of the trunk between the levels of 8 and 12 ft. from the stump. The timber either above or below this portion is slightly, though not very greatly, inferior.

The strength of ash with reference to its rate of growth

Tests of the same consignment of ash yielded figures which were used to determine what rate of growth gave the greatest strength in compression parallel to grain. Tests in compression parallel to grain were performed on 283 testpieces of varying rates of growth. The maximum crushing strength per square inch obtained from each of these testpieces is plotted separately against the rate of growth or rings per inch. The curve which is reproduced in Fig. 6 shows that ash reaches a good mechanical condition of structure when grown under conditions to produce from 6 to 11 rings per inch.

Comparison of English Ash with American Ash

A table is given below showing some of the mechanical and physical properties of several species of ash grown in Canada and the United States compared with home-grown ash, *Fraxinus excelsior*, as grown in the Forest of Dean. The timbers were tested in their green condition. It is interesting to note that from these figures there is very little difference in the average properties of the timbers.

Mine Timber

A considerable amount of work has been done on the testing of pitprops, mainly of home-grown species, to determine the comparative strengths of these species and also the influence upon strength of habitat and condition of seasoning. About thirty consignments of home-grown timbers have been tested in this way, and a comparison with the imported mine timbers has been afforded through the inclusion of some ten consignments, including Russian, Finnish, Swedish and French timbers.

The general results obtained show that among the home-grown timbers there is little to choose between the Corsican and Scots pines provided they have not been seasoned below 25 per cent. moisture content. Below this condition of seasoning the Corsican pine is inclined to show greater brittleness. Home-grown European larch appears to be a very satisfactory timber for this purpose, as is also Douglas fir when its rate of growth on the average is not greater than 6 rings to the inch. There is no foundation for belief that the strength of home-grown mine timber is inferior to that of imported timber when of similar grade.

The work on this investigation is proceeding, and the mechanical tests are likely to be concluded during the current year, after which a final report will be submitted. It is expected that it will be possible to give some indication of the best localities for the growth of good mechanical timber of the different species for use as mine timber, as well as a general comparison of the relative merits of the different species of home-grown timbers. Some comparison with the results on imported material will also be included.

Strength of Structural Timbers

The chief tests to be taken into consideration in the testing of timbers in structural sizes are—

(*a*) Static Bending.
(*b*) Compression Parallel to Grain.

Comparison of Mechanical and Physical Properties of Home-Grown and Imported Ash in its Green Condition

Species of Ash.	Locality where grown.	Weight per cubic foot as tested.	Linear Shrinkage.		Static Bending.			Impact.		Compression parallel to grain.	Hardness.	
					Fibre Stress.							
		(lb.)	Radial (per cent.).	Tangential (per cent.).	At Limit of Proportionality (lb. / sq. in.).	Equivalent at Maximum Load (lb. / sq. in.).	Modulus of Elasticity. (1,000 lb. / sq. in.).	Fibre Stress at Limit of Proportionality (lb. / sq. in.).	Height of drop of 50-lb. hammer (inches).	Maximum Crushing Strength. (lb. / sq. in.).	Side (lb.)	End (lb.)
Home-grown (*F. excelsior*)	Gloucester	51	4·8	11·8	3,900	8,200	1,430	11,900	56	3,540	890	1,040
Canadian White (*F. Americana*), (*a*)	Ontario	45	3·9	6·1	3,900	8,600	1,620	11,600	59	3,470	900	940
Canadian Black (*F. nigra*), (*a*)	Ontario	56	4·3	8·2	3,000	6,500	1,290	10,700	62	2,470	740	770
United States Blue (*F. quadrangulata*), (*b*)	Kentucky	46	3·9	6·5	5,700	9,600	1,240	11,100	43	4,180	1,030	1,140
United States Green (*F. lanceolata*), (*b*)	Missouri & Louisiana	48	4·6	7·1	5,300	9,500	1,400	11,400	34	4,200	870	960

(*a*)—Tested at Montreal. (*b*)—Tested at Madison, U.S.A.

These two tests include the general conditions of loading found in main structural members where the timbers either support loads on their sides which produce bending moments as in joists or beams, or are in end compression as posts or columns. In connexion with these two structural tests, minor tests of static bending, compression parallel to grain, compression perpendicular to grain, shear, and hardness are also carried out on small clear specimens obtained from the undamaged portions of the timber subjected to structural tests. Two of these, that is static bending and compression parallel to grain, are used more or less as control tests to show how the timber, tested in large sizes, compares with other timber when selected free from defects. The minor testpieces are cut from the undamaged portions of the members tested in static bending, either from similar parts of the columns or from parts cut, when convenient, from the columns before test.

The transverse tests of beams—ranging from 6ft. to 22 ft. in length—are carried out by the 4-point method, that is the beam or testpiece is supported at the two ends and loaded at two intermediate points, usually the points of tri-section with reference to the length or span of the beam. By this method a condition of uniform bending moment is obtained over that portion of the beam which lies between the two loading points. A deflectometer is attached to the beam to indicate the deflection produced by the application of the bending moment, and the elastic and other properties of the beam are calculated.

Experience has shown that the apparent ultimate strength of a beam is considerably influenced by the rate at which the load is increased during the test. It is thus necessary to apply the loads during test at a uniform rate, and to repeat the same method and rate of loading for any other beams which are to be compared. The rate at which the load is actually applied depends upon the nature of the machine and the facilities for doing the test. It has been found convenient to choose an arbitrary rate of increase of stress in the extreme fibres of the member in static bending of 200 lb. per sq. in. per minute.

In the testing of columns, the columns are supported in the testing machine between compression plates which give the effect of pin ends, and thus eliminate the influence of the shape of the ends of the specimen. The compression of the member during test is measured and at the same time the lateral deflection is observed.

Not only must the general structural characteristics of each specimen be carefully recorded, but also its defects both in size and location. A dimensioned sketch must be made of each of the four faces of a squared timber showing the actual size and location of each knot, split, or other defect, and it is usually customary to supplement these drawings with photographs.

The testing then proceeds, and the behaviour of the specimen during test and especially any tendency to fail at any of the defects is carefully noted. Through the production of a uniform bending moment over a comparatively long length of the specimen, the detection of the weakest point in the timber is assured, and the failure will in turn indicate the particular defect which has had the greatest influence in weakening the general strength of the timber. It is thus possible to calculate from the results of a large number of tests of this sort the influence of the various types of defects as regards their size and degree, and thus to allot to each one a factor which represents the influence of the defect upon the strength of a piece of clear timber of the same dimensions.

Work on this investigation has only just been begun. The aim of the investigation, as already stated, is to test timbers in large sizes and to produce a catalogue of the defects which occur in such timbers and to attach to each of these defects a factor

which may be applied in calculating the probable strength of a structural timber. This method of calculation should ultimately replace the old method of percentage testing. Once the existing grades of timber have been collated and tabulated with reference to their allowable defects, the remaining steps should not present any great difficulty. They will simply entail the application of the factors represented by these defects, so as to give the safe working stress to be allowed for the respective grade.

Architects and builders will then have at their command a series of tables from which they will be able to choose those timbers which have the equivalent structural strength, or to substitute, when the economic conditions demand, a timber of similar characteristics for one hitherto employed.

Influence of Treatment

Investigations of considerable importance have been progressing in conjunction with the work on Seasoning. These have to do with the influence of seasoning upon the strength of timber, and subsequently the determination of the type of kiln-seasoning treatment suitable for a given species of timber. In such investigations it is customary to select, before treatment, a number of specimen boards or planks, and to divide these into matched samples, putting one half aside to be tested as received and the other to be tested after treatment. These results will indicate the directions in which modifications of temperature and humidity should be made during seasoning in order to produce a desired effect on the mechanical properties of the timber under test.

A short time ago it was found that a certain transport company, using large quantities of ash in their vehicles, expressed the opinion that the strength of kiln-seasoned ash deteriorated upon storage. A suitable supply of ash as used in the construction of vehicles was obtained. This material was divided into two equal parts, the one to be stored without kiln treatment and the other to be treated in the kiln and then to be stored and tested at definite periods. The periods of storage were determined arbitrarily as six months, one year, two years, and three years. Material in suitable quantities for tests at these periods was stored, and with it a similar quantity of ash in the condition as received. As each one of these periods elapses the treated and untreated ash allocated for test at that period is withdrawn from store, converted into testpieces, and tested, So far the tests on material as received, at six months, and one year, have been carried out, and these tests clearly demonstrate that there is no foundation for the opinion that the properties of kiln-seasoned material when stored with reasonable care are in any way inferior to those of the air-dried ash.

Investigation into Properties of British Oak

An investigation of some magnitude is proceeding into the mechanical properties of the two species, sessile and pedunculate, of British oak, *Q. robur*. The investigation includes oak collected from different parts of the country where it is grown under widely differing conditions both in soil and climate. The mechanical tests employed are similar to those used in the testing of small clear specimens of timber, but the full schedule of tests is not followed, only those for static bending, compression parallel to grain, and hardness being carried out. Should any very marked differences in these mechanical properties become evident as the investigation proceeds, further tests will be made in order to confirm the apparent trend in the properties of the timber.

Influence of Fungal Attack

Although a complete scheme has not yet been formulated to deal with the methods of assessing the influence of fungal attack upon the mechanical properties of timber, yet

a considerable amount of preliminary investigation has taken place, especially with reference to the dimensions of the testpieces and methods of test. The great difficulty in such an investigation is to relate the degree of fungal attack to the corresponding strength of the timber, and in order to accomplish this it is proposed to produce a fungal infection in a small block of timber, and to test small specimens cut from the block at predetermined intervals. The size of specimen which is likely to provide a reasonably uniform condition of infection must necessarily be small, and for this purpose a static bending test specimen $\frac{3}{8}$ in. square in section and 5 in. long has been selected.

An attachment to test these miniature specimens has been designed and made in the laboratory, and satisfactory tests have been carried out on it, and the investigation will proceed as soon as the necessary conditions have been produced in the infected material to be tested.

Trials were made in testing still smaller specimens of $\frac{1}{4}$ in. square section on a span of 2·8 in. with a view of determining the relation in strength between summerwood and springwood That satisfactory comparative tests could be performed on such small specimens was proved, and further work on the subject is proceeding.

Properties of Plywood

Tests of considerable importance have been carried out on the comparison of properties of plywood with those of various types of manufactured wall-board. Special appliances were produced in the Laboratory to give an indentation test to show how these materials would resist puncture through sharp bodies coming in contact with them, and deformation tests to show how sheets of material would resist permanent deformation through the action of external forces.

Information and Advice

Besides two publications dealing with the work of the Section which have appeared lately, [1], [2] a considerable amount of information is supplied either directly to inquirers calling at the Laboratory, or by letter. In many cases the information required is the comparison of the relative properties of different timbers as regards their mechanical strength. There is apparent at present a commendable desire in many quarters to employ home-grown or Empire timbers wherever possible. To put this into practice entails in many instances the substitution by the user of a timber with which he is unfamiliar for a foreign timber which it has been his practice to employ. It is in such problems as this where the use of the comparative tests of a species of timber are of greatest help.

Assistance has been rendered to H.M. Office of Works in the preparation of specifications to allow the substitution of Empire timbers for others that are not of Empire origin. Other bodies, both public and private, are also, at present, seeking similar information.

Examples of information supplied to inquirers, during two weeks, taken at random, are as follows :—

- The relative merits of various spruces and Australian red gum for the manufacture of compressed wood.
- A report on the probable uses of mgongo, a Rhodesian timber.
- Advice on the tests required to indicate the suitability of hendui, a timber from Sierra Leone, for bridge building.
- A report on the probable reasons for the irregular behaviour under test of specimens of ash tested by the Southern Railway.
- A report of tests of wooden wall-bars of different species for gymnastic equipment of the L.C.C. Schools.

Equipment

An idea of the general equipment of the Testing Laboratory may be obtained from Fig. 7, and some description of the various machines may be of interest. Although many of the machines are of the universal type, various modifications have been introduced to make them more suitable for testing timber. There are three major testing machines (see Fig. 8), one having a capacity of 200,000 lb. and the other two of 100,000 lb. each. These machines are operated by hydraulic pressure from an accumulator producing a hydrostatic pressure of 2,000 lb. per sq. in. Each of these three machines is arranged to take transverse tests on spans up to 20 ft. Besides these hydraulic machines there are nine universal machines of the compound lever type. Each of these machines is motor-driven, and is arranged with appropriate controls and tachometer so that any desired speed of the motor may be obtained. By this arrangement it is possible to produce any desired rate of strain in the specimens, and to arrive at the conditions with reference to rate of strain, that are required in the testing of small clear specimens.

For impact tests two machines of the drop-hammer type have been installed (Fig. 9). In this type of machine the transverse specimen supported at the ends receives successively increasing blows from a weight raised to different heights and allowed to fall. The weight is raised by an electro-magnet and is dropped through the automatic action of the mechanism. This type of machine gives a record of the behaviour of the timber within the elastic limit, and also provides a measure of the toughness of the timber from the record of the maximum height from which the hammer is dropped to produce complete failure of the specimen.

The testing of small clear specimens, and also of various manufactured wooden parts such as, for example, gymnasium wall bars and shunting poles, is carried out on the motor-driven universal machines and the impact machines. Structural tests are in progress on the large hydraulic machines.

The equipment of the Laboratory also includes a pendulum impact machine of the Isod type having a capacity of 30 ft. lb. Another machine embodying the principle of impact through the action of the pendulum takes a transverse specimen 8 in. between supports, and applies to the centre of the specimen an impulse through the action of the stirrup and flexible connexion to a drum around the pivot of the pendulum.

It is a matter for satisfaction that as a result of the demand for equipment for mechanical testing of timber, the British manufacturers of testing machines have responded in such a way as to have now on the market testing machines which compete favourably with foreign machines of similar character which have been used in the commercial testing of various products. The equipping of the Laboratory with these British-made machines has served as a good example and advertisement, and as a result these machines of British manufacture have been sought for in distant parts of the Empire for installations where formerly machines of foreign make would have been selected.

(1) Chaplin, C. J. Mechanical and Physical Properties of Timber. *Forest Products Research Project* 1. H.M. Stationery Office, London. Price 2*s*. 0*d*. net.

(2) Chaplin, C. J. Tests on Some Home-Grown Timbers in their Green Condition. *Forest Products Research Project* 1. *Progress Report* 1. H.M. Stationery Office, London. Price 9*d*. net.

FIG. 7.—General view of the Timber Mechanics laboratory.

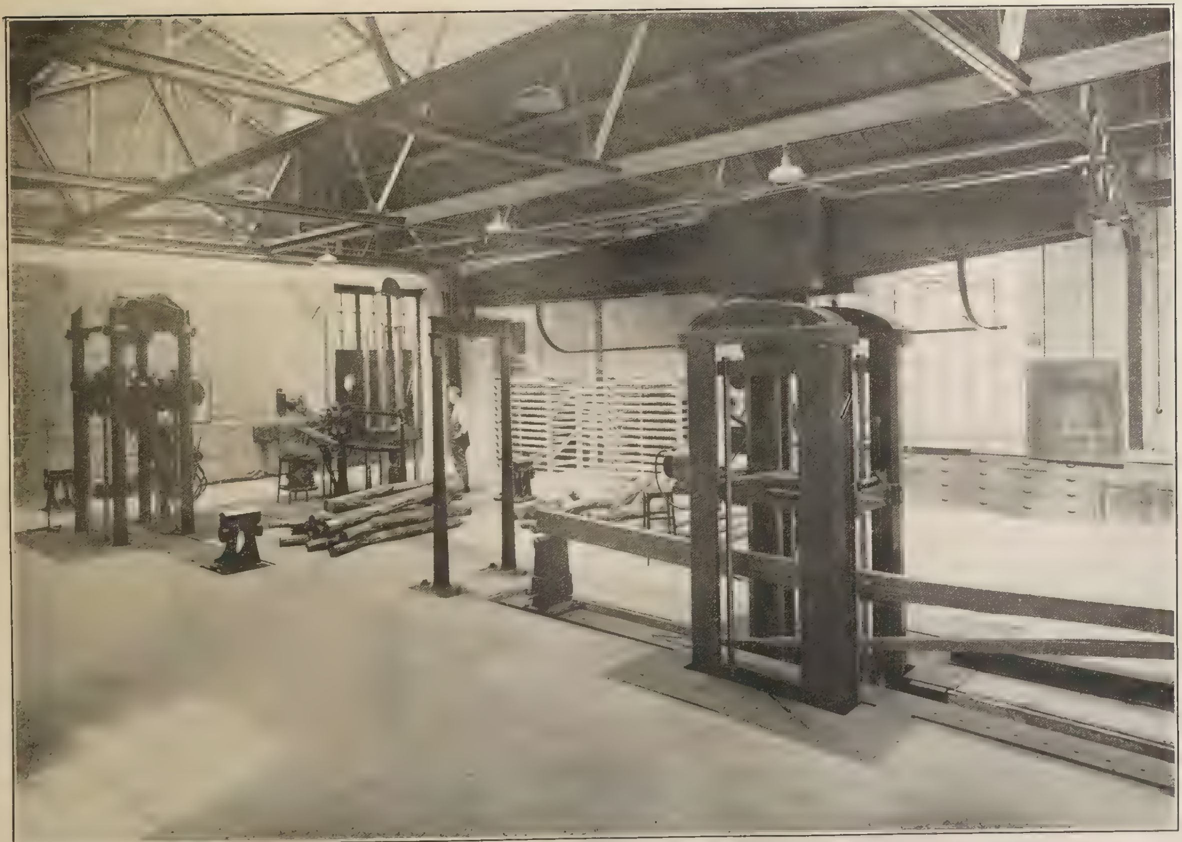


FIG. 8.— View of the three hydraulic testing machines, showing a structural timber tested to destruction, and tests on the strength of pitprops.

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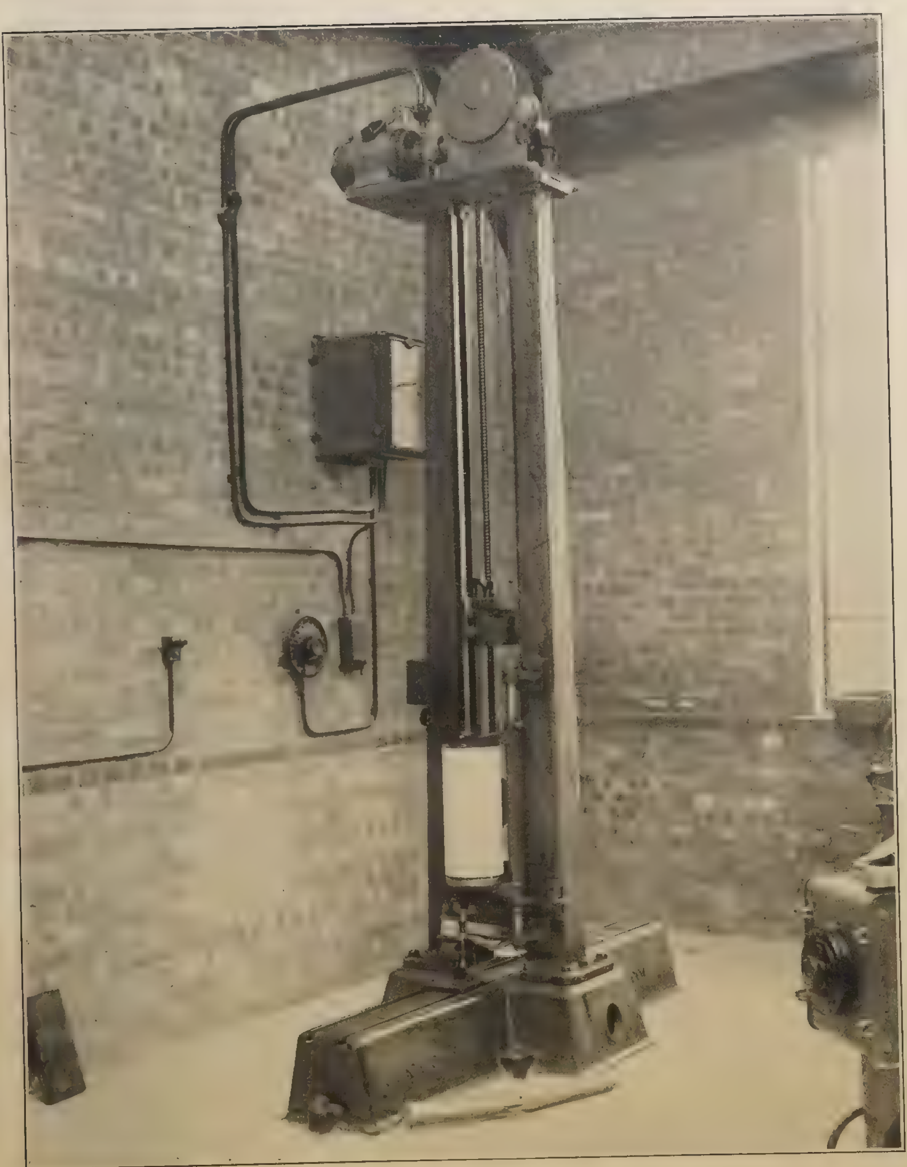

FIG. 9.—Impact testing machine: specimens tested to destruction.

Wood Preservation

A serious drawback to the use of timber for structural purposes is its susceptibility to the attack of fungus and insect pests and consequent lack of durability. Methods of protecting timber from these wood-destroying agencies have been practised for hundreds of years, but it is only during the last century that the antiseptic treatment of timber has been introduced and found to be satisfactory. Its use is by no means universal, although its efficiency is undisputed, and it is the object of the Laboratory to further the economical preservation of timber, both by the use of antiseptics or by any other efficient method.

Generally speaking, timber preservation is not practised in this country to nearly the extent that it might be with advantage. It is estimated that only about 1 to 2 per cent. of the pitprops used are treated in any manner, and excepting railway sleepers, timber used in harbour works and telegraph poles, the major portion of the structural timber used is not treated with antiseptics except by haphazard and inefficient methods. This may be due to lack of reliable information and instruction on the preservation of timber, or to reluctance to try new preservatives and methods of preserving, about which little is known and of which the efficiency cannot be determined for a long period, or to the cost of antiseptic treatments.

Consequently, the work of the section falls into two categories: (1) Advisory, (2) Research. Information from all sources is collected and together with information obtained by laboratory work, is co-ordinated and made easily available for the timber user. Numerous inquiries for advice and information on the preservation of timber are received and dealt with. A more specific example of the work in progress is a scheme which is on foot for placing in the mines a large number of pitprops treated with different antiseptics. The efficiency of these antiseptics is known from records, mostly foreign, but an ocular demonstration is much more convincing to the user—in this case the colliery managers. The experiments will also provide reliable data on the life of treated mine timbers.

To support the advisory side of the work, definite research work is undertaken to obtain the best information to pass on to the timber user. An example of this is the work on the standard tests of antiseptics. The object of these tests is to obtain comparative values of the effectiveness of various antiseptics as preservatives of timber against fungal decay and insect attack. Briefly, the scheme is as follows. Specimens of different species of timbers are treated with the antiseptic by a standard method and, together with corresponding controls of untreated specimens, inserted in the ground as stakes. They are inspected periodically and a record kept of their durability. A similar series of specimens is placed in a specially prepared chamber, kept at a temperature and humidity most conducive to the growth of wood-destroying fungi, and a similar record kept of their durability. The treatment and the species of timber are the same for all antiseptics. These tests will of necessity be extended over a long period of years, but it is considered that this test under actual conditions of use is the most conclusive. In conjunction with these tests, laboratory mycological tests are being carried out (see page 52) on the antiseptics made up to varying concentrations in a nutrient medium. Also small specimens of wood treated with different concentrations of the antiseptic either dissolved in or emulsified with water are inoculated with a fungus under special conditions, and the lowest concentration found which inhibits growth. These latter tests give a quick indication of the toxicity of the antiseptic. Similar specimens of treated wood are also subjected to the attack of wood-boring insects. When preservatives of long standing have been tested under

this scheme all new or suggested preservatives will be tested in a like manner and their efficiency compared with that of preservatives of known worth.

The Laboratory has conducted a series of experiments on the strength, seasoning and durability of home-grown Corsican pine, with a view to its use as a structural timber. The timber has been found to absorb preservatives very readily, and on account of the large percentage of sapwood the penetration is deep and uniform. Weather boarding cut from this timber has been treated with different antiseptics and erected round the Laboratory saw-mill, different bays being devoted to different treatments. A record will be kept of the durability of this boarding, which will furnish data concerning the efficiency of the preservatives under these particular conditions and also the durability of this comparatively new timber. Similarly, a number of fence posts have been treated in different ways and with different antiseptics, and the life of these posts will furnish most valuable data, not so much perhaps as to the method which will give the longest life, but more as to the most economical proposition for any particular case. Economy of treatment is, of course, a primary object kept in view in the research work, and in this connexion the development of preservatives which may be as efficient as creosote and not nearly so expensive, is regarded as of outstanding importance.

Another section of the work is the testing and trying out of different appliances and methods of applying the preservatives to the timber, with a view to finding out the most efficient method of treating any particular timber for any particular purpose. An instance of this is the treatment of Douglas fir. This is a refractory timber which cannot be successfully treated by the same methods as at present used for Scots pine, and consequently new methods have to be adopted to deal with this timber, of which comparatively large quantities have been imported into this country in recent years. It has been arranged to carry out experiments to determine the best method of treatment. Similar experiments will be carried out on larch telegraph poles, which are, at present, looked on with disfavour mainly because of their resistance to treatment. Tests are being carried out on a proprietary patented machine for the treatment of timber *in situ*, particularly telegraph poles, fence posts, and the like.

The scope for research work is very wide. Some of the important problems that await investigation and with which it is hoped to deal in due course are: the preservation of structural timber attacked by the Death Watch Beetle, the protection of timber in timber-yards from *Lyctus* attack, the prevention of dry-rot in houses, and the development of fire-retarding preservatives for special purposes.

The Laboratory is equipped with a pressure impregnating plant, in which timber can be treated by any of the better-known processes, and which can be used with any preservative which has no serious corrosive action on iron. A general view of this plant is shown in Fig. 10

Woodworking

A very important quality in wood is the way in which it lends itself to working and machining under a tool. Definite information on the subject is often as important as data on strength factors, seasoning qualities and durability when determining the possible uses to which timbers, not at present in common use, may be put.

The working and machining qualities of timbers in common use have been ascertained by long experience, though even now, on account of the personal factor, wood machinists, cabinet-makers, and carpenters are not always in entire agreement on all points. To overcome this difficulty a programme of work has been drawn up, according to which each timber, the working qualities of which are unknown, will

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FIG. 10.—Wood Preservation Plant.

be subjected to definite tests. In carrying out these investigations the power necessary to plane, saw, drill, etc., a standard sized specimen, both quarter-sawn and slash-cut, is definitely measured. In the case of planing and spindle moulder tests, the surface obtained under a standard tool, revolving at a definite speed, with the specimens fed at a fixed rate of speed, will be recorded by a special surface recorder. Different types of tools and saws, each ground to standard angles of cut, set and pitch, will be tried to determine the most suitable for use with any individual species of timber. By such methods it is hoped to eliminate the personal equation, though it is proposed at the same time that the expert machinist or cabinet-maker entrusted with the work should record his personal opinion as to the behaviour of the wood under the tool. Such information as may be collected by carrying out the provisions of the project would be of little use to the trade were not similar information available for timbers in common use, on which to base comparisons with results of tests carried out on new species. Tests will also be carried out by carpenters and cabinet-makers with hand tools, and the finishing and polishing qualities of the timber will be determined.

Attempts have been made in the past by forest products laboratories to carry out woodworking tests, but so far as is known the information collected has always been based on the opinion of the craftsman employed and not from tests carried out according to more precise methods of the kind laid down in the scheme of operations outlined above.

Mycology

Original research is being carried out at the Laboratory on the decay of wood by fungi and on the measures to be taken to minimise the amount of damage done. Whereas, in the past, empirical methods of controlling fungal decay have been largely employed, it is the intention of the Laboratory to carry out fundamental research which will enable remedial measures to be placed on a surer and more scientific basis. In addition, inquiries are dealt with and advice is given to those engaged in handling or using timber on the means by which fungal attack of timber can be avoided. Some aspects of the work are, of course, considered jointly with other Sections of the Laboratory.

Comparatively little research has been done in this country on the decay of wood by fungi, and very little accurate information is available either as to the effects of various fungi on different timbers or as to the conditions which determine whether a particular piece of wood is attacked or not. Hence the research work which has been started falls into two groups—(*a*) the systematic observation of the numerous kinds of rot and of the fungi which cause them, and (*b*) the study of the physiology of the fungi with a view to discovering the exact conditions under which attack can occur and how it can be prevented.

Identification of Fungi

In the past, difficulty has been experienced in identifying the fungus responsible for a decay, especially when more than one fungus is present at the same time.

If a fruit body of the fungus is absent, as is frequently the case, correct identification by a mere inspection of the gross characters of the rot is extremely difficult. Even if the inspection is supplemented by a microscopic examination of the details of the mycelium in the wood and of the penetration of the wood elements, the identity of the causal fungus often remains obscure. It has, indeed, been necessary to wait, frequently for years, until the appearance of a sporophore rendered certain

identification possible: even after this long period the development of such a fruit body may not take place. On the other hand, it has been found that the cultures of wood-destroying fungi, after a few weeks' growth on a standard nutritive medium, exhibit characteristics which enable them to be identified, provided that already named cultures are available for comparative purposes. Accordingly one of the first tasks of the Mycology Section of the Laboratory has been to build up a series of type cultures derived from sporophores named by competent systematists. Most of the common fungi which cause decay of wood have now been collected and cultured. A number of cultures have also been obtained from Canada and America, where the importance of culture work in connexion with the identification of the causes of decay has already been recognized and where type collections have been formed at Ottawa and at Madison. It is hoped to add considerably to the collection so as eventually to include all the fungi likely to be found on material sent in for diagnosis.

The importance of this rapid aid to diagnosis should be stressed, for, once the identity of the fungus is known, the time and place where the decay originated can usually be determined. Decay may originate in the standing tree; during lumbering operations; in the course of shipment; or, if of the dry rot type, in docks or timber-yards, as well as actually in service. And it is important to know exactly where it originated in order that sanitary measures may be applied.

The characters of these fungi which have been found of value for identification purposes include the following: colour, texture, rate of growth, colour changes during development or on exposure to light, production of sporophores normal or abnormal or of bulbils or sclerotia. A study of the physiology will often help in diagnosis, and the rate of growth in relation to temperature and the reaction of the fungus to alkalinity or acidity have proved of significance. Identification can frequently be made on these visible characters alone. The microscope provides further aid, since it has been found that the mycelia of the fungi exhibit special characteristics. The most important points to be observed here are the range in size of the hyphæ, both aerial and submerged; the presence or absence of clamp connexions, the type of clamp connexion, the presence of thick walled fibres and the formation of secondary spores.

In addition to the collection of cultures a collection is being made of fruit bodies, of type rots produced artificially by pure cultures of fungi and of microscope slides which show details of the mycelium in the wood. Thus something in the nature of a reference library for the ready diagnosis of timber decay will shortly become available.

Wood Preservation

As mentioned elsewhere (see page 49), investigations are being made to arrive at some standardized method for comparing the toxicity of antiseptics, and preliminary work on this is in progress. The wood blocks will be treated with "preservative" and will be tested by exposing them to the attack of a pure culture of a wood-destroying fungus. It is proposed to carry out tests in agar also.

Relation between Insect and Fungal Attack

In collaboration with the Entomology Section, work is in progress on the relation which appears to exist between insect attack and the presence of fungus in wood. In the first instance a survey is being made of the frequency of the presence of fungus mycelium dead or alive in wood attacked by beetle. In every single specimen examined to date fungus mycelium has been found in wood attacked by insects. It is hoped in the near future to carry out controlled experiments.

In co-operation with the Imperial Forestry Institute, Oxford, examination is being made of the association of a fungus with the wood wasp, *Sirex cyaneus*. Very interesting and suggestive results have already been obtained. Pit-props which had been stacked in the open in the Forest of Bere were examined and, besides much fungal decay, were found to contain pupæ of *Sirex gigas*. At present, however, work is being confined to the *cyaneus* species. An investigation into the fungi which are found occurring in old oak that has been attacked by beetle is proceeding on material provided by Professor Groom, and a study is being made of the causes of the rich colouration often produced in such oak.

Dry Rot

The form of decay popularly known as "dry rot," caused by various fungi (notably *Merulius lacrymans*), is an evil the disastrous effects of which are only too familiar. The term "dry rot," though it aptly describes the brittle and dry appearance of the timber after attack, is not so fitting a description during an attack, for the presence of a certain amount of moisture is necessary for the growth of the fungi causing the decay: indeed, one of these fungi can, itself, produce in its life processes enough water to render the wood damp.

In spite of the familiarity of dry rot, large numbers of cases still arise in which decay has been invited by faulty building construction and improper use of timber, or when inadequate remedies are applied. It has therefore been thought advisable to issue a Bulletin [1] for general public information. This Bulletin presents in a simple and practical form the sum of existing knowledge of the subject, and is intended to assist recognition of the signs of the disease and to provide authoritative information concerning its prevention and remedy. The Laboratory is indebted to Professor Groom and representatives of the Ministry of Health, H.M. Office of Works, and the Department's Building Research Station for their help in the preparation of the Bulletin.

Although little research work has actually been carried out by the Laboratory into dry rot, useful information has been collected and special inspections have been made from time to time of infected buildings. Specimens of the fungi occurring have been collected and a study made of the conditions under which decay had taken place. The places visited included coal-mines, docks, and cold stores. During the autumn, frequent expeditions were made for the purpose of collecting fungus material in the field.

In this connexion mention may be made of assistance given to a Linoleum Company in carrying out tests, using various processes and antiseptics, with experimental floors at the company's works. Tests have been made in the Laboratory on the power of *Merulius lacrymans* to attack the linoleum itself, and it has been found that pieces of linoleum which had been in contact with an actively growing culture of *Merulius* for six months were entirely undamaged.

From time to time further attempts have been made to germinate the spores of *Merulius lacrymans*, but without success. It is intended to continue working on the problem.

General Research

As time permits, research will be undertaken on the life-histories and physiology of the principal wood-destroying fungi. Work is on hand on *Paxillus panuoides*, though progress has been somewhat slow owing to the lack of fresh material. In working

out the physiology of these fungi the rate of growth in relation to temperature will be determined and curves will be drawn to show this. The important problem of their water requirements will also have to be investigated.

Special Investigations

Broadmoor Asylum.—A short investigation has been made on two fungi suspected of causing decay of timber in Broadmoor Asylum. It was found that the two fungi under review were of very little economic importance and that dry rot (*Merulius lacrymans*) was the main cause of the trouble.

Deterioration of Sitka Spruce (Aeroplane Spruce).—At the request of the Air Ministry an investigation was begun in 1924 to determine the fungus responsible for the decay during storage, and consequent loss of valuable material, of some of the Sitka spruce shipped to this country for aeroplane manufacture. A number of fungi have been isolated in pure culture and the principal one responsible for the decay has been identified by a comparison of cultures, as *Trametes serialis*, a fungus that is common in Canada. Subsequent, but much later, development of fruit bodies has proved this identification correct. A careful study of the action of this fungus on spruce wood has been made, and a report is now in preparation for publication.

Brashness of Ash.—Work was started on a study of the causes of brashness of ash and a preliminary paper on the brashness caused by *Polyporus hispidus* is being published .

Advisory Work

During the past year numerous inquiries have been answered and many specimens identified. These have been mostly connected with dry rot in houses, for which preventive or remedial measures have been suggested. Inquiries have also been received concerning the cause of decay of telegraph poles, railway sleepers, furniture timber, pitprops, and the like.

[1] Dry Rot in Wood. *Forest Products Research Bulletin No.* 1. H.M. Stationery Office. 1928. Price 1*s*. 6*d*. net.

[2] NUTMAN, F. J. Preliminary Account of Brashness in Ash. (*In the press.*)

ENTOMOLOGY

The losses caused by the ravages of wood-boring insects in timber, from the time it is felled until it is put into service, are much greater than is generally realised. In order to check or prevent such losses attempts have hitherto been mainly devoted to the invention of remedial measures. But it has become evident that before satisfactory measures can be devised it is first necessary to ascertain what groups of insects are most injurious to timber, and to study their life-history and rate of development. Accordingly, such studies constitute the immediate work of the Entomology Section of the Laboratory.

A series of outdoor insectaries (Figs. 11 and 12) have been erected and are used for storing large quantities of timber attacked by the different insects concerned. In this way numbers of adult insects can be bred for use in the numerous experiments carried out within the Laboratory—experiments necessary for the study of the life-cycle and habits of the different species or for testing the value of various insecticides and wood preservatives against insect attack.

FIG. 11.—Field insectaries for storage and study of insect-infested timber.

FIG. 12.—Structure of an insectary: note double doors.

Lyctus Powder-Post Beetles

Early in 1925 a group of furniture manufacturers approached the Forest Products Research Laboratory for advice and assistance concerning "worm" in oak and ash. Serious losses were being caused by insects which on investigation were found to be species of powder-post beetles (Family *Lyctidæ*). The matter was taken up by the Laboratory and an inquiry instigated into the extent of the damage caused by these insects and into possible methods of checking their ravages.

This investigation has yielded information of direct value to the furniture industry and timber trade generally. *Lyctus* powder-post beetles have been shown to be causing losses in this country not only to furniture trades, but to all industries in which quantities of sapwood of certain hardwood timbers (oak, ash, walnut, sweet chestnut) are used. The insect confines its attacks to the sapwood, which is, in time, reduced by the feeding larvæ to a fine flour-like powder—hence the name "powder-post beetle." It has been shown that whereas formerly only two species of *Lyctus* occurred in this country, there are now four species to be found in timber-yards, stores and factories in Great Britain. Evidence has been collected which indicates that the increase and spread of *Lyctus* are due to the importation of American oak and ash already infested with these insects.

Sterilization of timber by heat for the destruction of wood-boring insects was initiated in the United States of America, where experiments were conducted by Craighead and Loughborough (2) with the red-headed ash-borer, *Neoclytus erythrocephalus*, and by Snyder (3) with the powder-post beetle, *Lyctus planicollis*. Attention has been concentrated by the Forest Products Research Laboratory on the application of such methods in this country as the most economically sound means of control suitable for adoption on a large scale and as providing a sure method of ridding timber-yards and factories of *Lyctus* powder-post beetles.

In continuation of Snyder's work in America a series of experiments has been carried out in co-operation with the Seasoning Section, results of which may be summarized as follows:—

i. Temperatures below 125° F. with relative humidity of kiln atmosphere at 100 per cent. are not fatal to *Lyctus* when maintained for $1\frac{1}{2}$–2 hours.
ii. Temperatures of 130° F. and above with relative humidity of kiln atmosphere at 100 per cent. maintained for $1\frac{1}{2}$ hours, after the timber in the kiln has reached these temperatures throughout, are fatal to *Lyctus*.

These results so far confirm Snyder's experiments, but indicate that the actual lethal temperature is less than 130° F. In December, 1927, a demonstration of this kiln treatment, carried out on a commercial scale in one of the Laboratory's kilns at Princes Risborough, was given to a representative gathering of timber merchants, furniture manufacturers and others interested. Much interest was shown in the demonstration, many questions were asked and information sought on different aspects of the problem of "worm" in timber and furniture.

Further work is in progress to ascertain how far lower conditions of temperature and humidity and longer periods of treatment in sterilizing kilns can be employed to kill the insect in all its stages.

Sterilization by heat does not render timber immune from re-infestation by *Lyctus*. It is therefore necessary to determine practical ways and means of rendering timber free from further attack. It is essential that any substance used for such a purpose must penetrate completely the sapwood and must not seriously affect the colour and working qualities of the timber. At the same time the method of treatment

must be cheap and simple to apply. Preliminary work on this problem has been carried out, and it is hoped in time to find a solution.

During the course of the *Lyctus* investigations information has been collected on the relations of *Lyctus* to different timbers and the conditions which invite attack. In this connexion an attempt has been made by the Wood Technology Section of the Laboratory to determine what relation exists between the size of wood vessels in a timber and its liability to attack, by comparing series of measurements of the pores of a range of timbers which were found attacked by *Lyctus* with the minimum and average widths of a series of eggs of *Lyctus brunneus*. The results of this study [4] have shown that the size of pores in a timber as compared with the minimum width of a *Lyctus* egg determines whether or not the species is liable to attack. Woods possessing pores which are too small to allow of the insertion of a *Lyctus* egg are, apparently, immune from attack. Vessel size is thus a limiting factor. Figs. 13 and 14 illustrate the comparative liability to attack of the different timbers dealt with. It has also been shown [5] that the age of seasoning and moisture content of timber determines its susceptibility to attack. It has been stated by Snyder that timber seasoned less than eight months will not be attacked by this insect. The Laboratory experiments do not confirm this statement. Infestation of timber has been obtained in our investigations within one month of felling. On the other hand, where the moisture content of timber fell below 8 per cent. *Lyctus* did not develop.

A full report of the *Lyctus* investigation is published as Forest Products Research Bulletin No. 2 [6], and contains details of the experimental work which has been conducted as well as a general discussion of the economic importance of *Lyctus* powder-post beetles and the damage they are causing in this country.

Furniture Beetles

While most time has been devoted during the past year to the *Lyctus* problem, a start has been made with an investigation into the losses caused by Anobiid beetles to timber in buildings and in furniture. Two insects are especially concerned :—

i. *Anobium punctatum*, the Common Furniture Beetle, the commonest cause of " worm " in old furniture, and

ii. *Xestobium rufo-villosum*, the Death Watch Beetle, which has caused such serious damage to roofing and structural timbers in so many old buildings in this country (e.g., Westminster Hall).

These two insects between them cause more damage than has been fully realised. There can hardly be a private house in the country which does not contain at least one article of furniture in a " wormy " condition, due to attack by *Anobium*. Again, attention has been called repeatedly to the presence of Death Watch Beetle in old historic timbered roofs, and large sums of money have been, and, indeed, are still being spent, in attempts to arrest or prevent the ravages of this insect. In the past, as already stated, more attention has been given to methods of control and eradication of these wood-destroying insects by means of insecticides than to their biology, life-cycle, habits and rate of development under varying conditions, of which very little is known. In consequence of this, it is the policy of the Laboratory, first of all, to undertake a thorough and detailed study of the biology of the two insects concerned.

Anobium punctatum—the Common Furniture Beetle

In June, 1927, work was begun with *Anobium punctatum* because this was the easier insect to work with and because it was hoped that information obtained

would be invaluable when the more difficult problem of the Death Watch Beetle was tackled.

During the past year special attention has been paid to egg-laying habits and to the rate of development of the larvæ of *Anobium punctatum*.

The common furniture beetle may attack coniferous as well as hardwood timbers, and its egg, as distinct from that of *Lyctus*, is laid in cracks and crevices, or even on the wood surface, and is not hidden within the pores of the wood. It has been shown that in choosing a suitable place for oviposition *Anobium* prefers certain timbers —for example, beech was, apparently, more suitable than oak, which, according to Kemner [7], is avoided by this insect on account of its hardness. It is of special interest, also, to note that in our experimental work *Anobium* was found to show a preference for timbers containing fungi.

Experiments have indicated that the rate of development of egg and larva is governed by conditions of temperature and humidity. During the past year the growth of larvæ in the Laboratory has been very much slower than was expected, and it is evident that larvæ which have been under observation since emerging from eggs in June, 1927, will not reach the adult stage until the spring of 1929, at the earliest. As in the case of *Lyctus*, there is strong evidence that the age, moisture content, and other conditions present in the wood influence to some extent the rate of development of this insect. The results that have been obtained to date are of the greatest interest and are already leading to a better understanding of the conditions most suitable for the development of the common furniture beetle.

Xestobium rufo-villosum—the Death Watch Beetle

During the year work on *Xestobium rufo-villosum* has, of a necessity, been confined to the collection of quantities of infested beams from many buildings throughout the country. Stocks of insects from these are being reared at the Laboratory in order to have abundant material for the experimental work on the biology of this insect, which was begun in 1928. Information has also been collected on the conditions under which *Xestobium* has been found in roofing timbers. It has been suggested many times that the Death Watch Beetle may be associated with dampness, bad conditions of ventilation, or with the presence of fungus. It is the endeavour of the Laboratory to ascertain definitely whether there exists any relationship between fungal infestation of timber and progress of *Xestobium* or *Anobium* attack. The settling of this point may have high practical value and a very important bearing on the planning and ventilation of houses and other buildings. Progress has been made with this side of the investigation. Samples of wood attacked by Death Watch Beetles or by *Anobium*, collected from different localities, have been examined by the Mycology Section of the laboratory for the presence of fungi. In every case, the presence of fungus, alive or dead, has been detected—a significant result. Where possible, cultures are being made of fungi taken from this insect-attacked wood. It is hoped to identify these, or at least to determine whether their presence and that of Anobiid beetles may be correlated. The recent work of Buchner [8] has shown that the association of wood-boring insects with fungi may be far more general than has hitherto been imagined. The results of his researches indicate how important it is to ascertain whether any symbiotic relationship exists between fungi and wood-destroying beetles, and emphasize the necessity of accurate knowledge of the biology of these insects before successful and reliable ways and means of preventing their ravages can be devised.

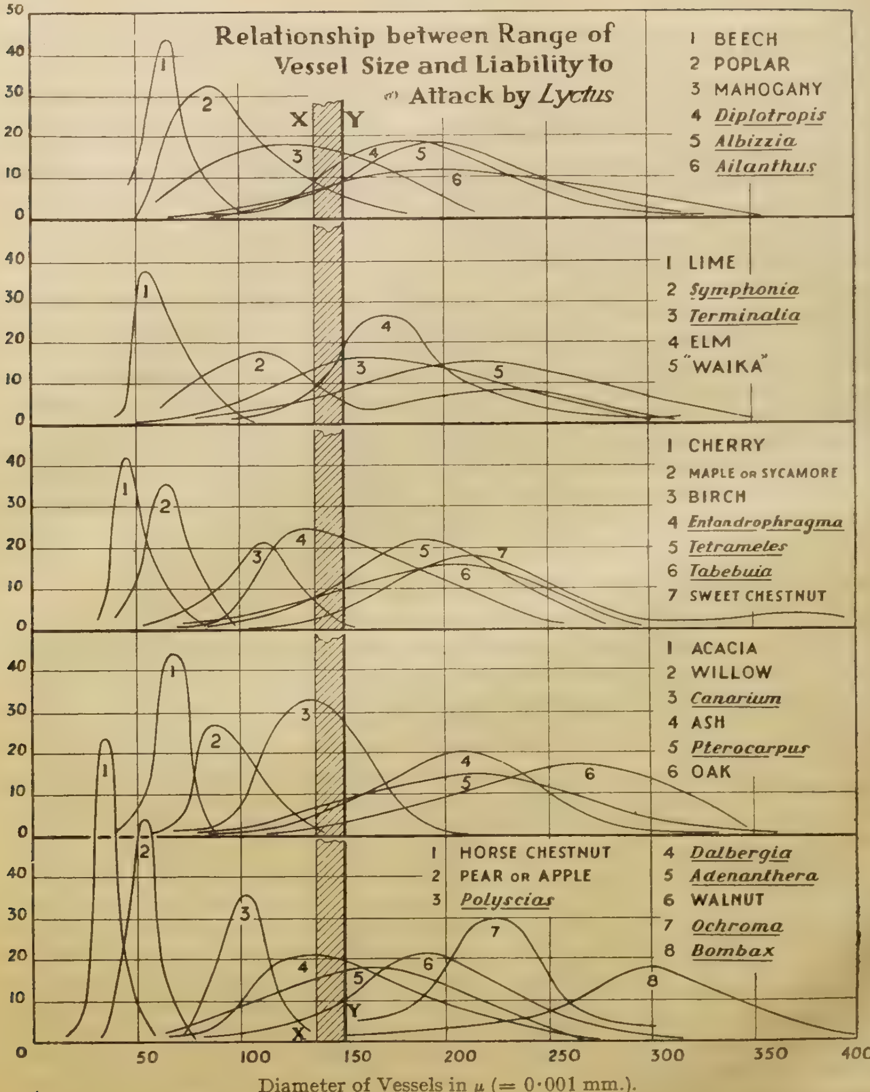

FIG. 13.—Normal distribution curves showing by genera the distribution of vessel size. XX is the minimum diameter recorded for the egg of *L. brunneus* (measured in the widest part). YY is the average diameter of the egg of *L. brunneus*.

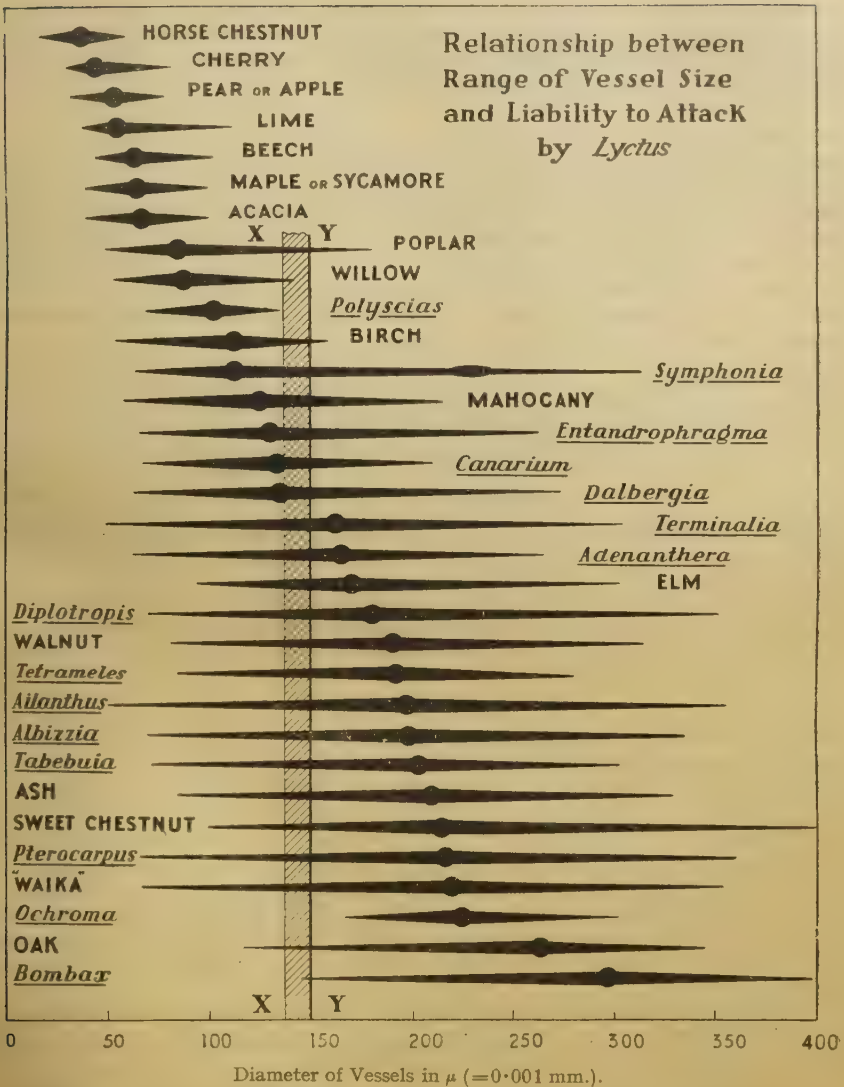

FIG. 14.—Woods arranged according to the vessel diameter which is most frequent in each genus (as revealed in Fig. 13). Length of curves indicates ranges of vessel size: centres of black discs indicate positions of the maximum frequencies. XX and YY as in Fig. 13.

Insecticide Tests

Pending the undertaking of a series of standard antiseptic tests, now in progress, in co-operation with the Wood Preservation Section, a number of preliminary tests with different insecticides and proprietary preparations have been carried out during the past year for the information of the Laboratory.

Advisory Work

Numerous inquiries have been received from furniture manufacturers, timber merchants, and users of timber generally, for information concerning insect damage to timber and means of control. Insect specimens have been sent for identification and samples of " worm "-eaten timber submitted for report. Advice has been given particularly with reference to heat sterilization of timber for the destruction of *Lyctus* spp. Advisory work is increasing. Much useful information on the insect conditions in timber-yards and premises has been obtained from such correspondence, as well as from surveys carried out in the course of the work.

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WOOD CHEMISTRY

Chemistry finds application in the general scheme of forest products research as an aid to discovering the true nature and composition of the raw material, so that preservative and seasoning treatments may be applied with greater certainty and the fuller possibilities of chemical conversion may be explored.

Until comparatively recently, research in this field has been hampered to a considerable extent by the fact that the literature of the subject was scattered throughout a wide range of publications. Standardized analytical procedure was unheard of. However, with the appearance of two textbooks in 1926 [1] [2] and a third in 1928 [3] the province of wood chemistry has been defined, its literature has been carefully indexed, methods of analysis laid down, and the real possibilities of the subject expounded.

In addition to its well-known structural and decorative value, wood is recognized as the chemical source of an ever-increasing range of important commercial commodities. These may be divided into two main groups :—

(i) " Extractive " substances such as gums, oleoresins, tannins, etc., which are present in the cell cavities, which do not form part of the actual vegetable skeleton.

(ii) Products—such as wood pulp—obtained from the actual wood substances by various physical and chemical processes.

Some woods are of value mainly for their extractives, but when it is recognized that extractives by themselves form but a small portion of any particular wood, and that all woods, considered quite apart from extractives, are approximately of the same composition, it is obvious that the attention of the wood chemist proper must first be applied to the woody cell wall, its composition, and the inter-relations of its components.

Wood is in no sense homogeneous, for insomuch as it is composed in a physical sense of groups of cells of varied function and structure, the actual cell wall substance is divisible into certain more or less definite chemical components of entirely different constitution and properties. In the present state of its development, however, wood chemistry does not seek to trace out the steps of wood formation—or lignification—in the living tree; it is concerned, rather, with wood substance, the elaborated and dead material.

The Hemicelluloses of Timber

A preliminary investigation [4] on American white oak sawdust has shown that a substance, or substances, amounting to 8 or 9 per cent. of the original weight of the sawdust could be obtained by the action of cold dilute alkali. This substance resembled closely a product known as "hemicellulose," obtained many years ago in a similar manner from leguminous seeds, from the bran of wheat and rye, and more recently from turnips, onions, pea-pods, oranges, and various kinds of starches.

It was evident that if the product obtained from every one of these sources possessed similar chemical properties, it must have a wide distribution in nature. Its further investigation was therefore undertaken first of all at the Imperial College of Science and Technology and later under the supervision of Sir James Irvine at St. Andrews University, in the hope of ascertaining its function in woody tissue and especially the part played by it in the chemical changes attendant upon lignification. As these changes, of which very little is known, are closely connected with differences in the structure of wood, the knowledge thus obtained should ultimately be of assistance in solving some of the problems connected with the drying and seasoning of timber.

Sawdust from beechwood varying in age from 80 to 130 years was treated in a similar manner. It was found that two substances (hemicellulose "A" and "B") were extracted by the alkali, each possessing different chemical properties, and that the percentage of one of them became less as the tree advanced in age. It was also found that the hemicelluloses were much more akin to the pectic substances than to cellulose.[5] [6]

A third series of investigations—on American white oak heartwood—was undertaken with the view of obtaining some information of a more definite nature about the chemical constitution of these substances, and although it has not been possible as a result of these investigations to assign a chemical formula to the hemicelluloses it has been shown that they bear little or no resemblance to cellulose. Another interesting fact which has been brought to light is that the chemical nature of hemicellulose apparently alters with the age of the wood, and that in very mature wood it appears to bear a resemblance to lignin. An additional result obtained has been the identification in the hemicelluloses of methoxyl, a constitutional factor which enters largely into the composition of both pectin and lignin. [7]

A new series of investigations on a large quantity of British oak (*Quercus sessiliflora*, Salisb.) is now being pursued in the hope of gaining additional information on several different points and also of making new discoveries in this field. The sapwood and heartwood are being treated separately and sawdust has been obtained from each

in the green state and also after being oven-dried and dried in the kiln. These investigations should prove definitely whether, in the first place, the chemical nature of the hemicelluloses is dependent on the age of the wood—a most important point—and whether, in the second place, the presence of methoxyl in the hemicelluloses is evidence in support of the fact that these substances partake of the character of both pectin and lignin. In connexion with this statement it should be noted that a well-known German plant chemist has recently suggested [8] a transition in the plant from pectin to lignin, and has brought forward much evidence in support of this view. The fact that pectin is found in much larger quantities than the hemicelluloses in unlignified tissue, and that the reverse holds true for lignified tissue, taken in conjunction with the other evidence available, should also support the view that the hemicelluloses are transition products in this great natural transformation, and that, consequently, their influence on the chemical nature of the structure of wood is of great importance.

General Work

Other aspects of Wood Chemistry have recently been given attention, and a programme of work has been drawn up covering (1) the analysis of wood for statistical purposes, (2) the effects of insects and fungi on wood substances, and (3) the effects of chemical reagents on wood.

In the first instance a study is being made of the effects on oak sapwood of the larvæ of the *Lyctus* powder-post beetle, in the hope of proving definitely whether or not wood is used by the insect as food. This important point in the biology of the beetle is not yet settled.

Investigations are also under consideration with a view to determining the chemical nature of the early stages of fungal decay. It is known that both fungal decay on the one hand and acid hydrolysis on the other, have the effect of increasing the alkali solubility of wood, and the aim is to find out whether decay in its early stages might be strictly comparable in a chemical sense with simple acid hydrolysis.

In the course of time it is hoped to go into the question of the effects of various chemical reagents on wood so as to obtain a closer insight into the chemical identity of cellulose and lignin respectively. At present cellulose is regarded as by far the most important wood constituent, and is therefore the objective of nearly all chemical conversions of the material, while lignin is, in the main, wasted. Fundamental research may provide a means of developing more intensive utilization.

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Utilization

It will be obvious from what has already been written that, while the work of each section of the Laboratory is mainly of an investigational character, the application of the results obtained to everyday practice is always borne in mind. This " utilization " work is supplemented by the activities of a special Utilization Section which has

been formed to serve as the main link for general purposes between the Laboratory and the outside industry.

Every effort is made by the Laboratory as a whole to become acquainted with the wood-using and wood-working industries, so that friendly contacts are established and first-hand impressions obtained of the difficulties with which the industries are faced and in which the Laboratory can give assistance. In this way the nature of the research work undertaken is harmonised with the results possible of attainment under industrial conditions. It then becomes much easier not only to bring the results home to the industry when they are attained and to note the uses made of the advice given, but also to secure, when occasion arises, that full advantage is taken of the facilities which the Laboratory can offer.

With a view to affording direct assistance in answer to inquiries, data are collected as to the qualities of timbers required for different purposes. For example, ways and means are considered of introducing new species of timber on the market ; in particular, attempts are made to substitute species of Home or Empire origin for those imported from foreign countries, with due regard to established trade practices. Again, help is given in framing specifications, and avenues are sought for more remunerative uses of waste material in saw-milling and wood-using industries.

From another aspect, the work of the Utilization Section is the binding together of the work undertaken on special subjects by other sections of the Laboratory. Thus it may happen that a question arises as to the uses to which a hitherto unexploited species of timber may be put. The answer to this question may depend, amongst other things, on the seasoning qualities of the timber, its mechanical properties, its susceptibility to machining and polishing, and on a knowledge of the uses made of comparable timbers. Accordingly, once the investigations of this character to be undertaken by each section have been planned, it may fall to the Utilization Section to link together the various reports and to present a covering report to the inquirer in a form which will best suit his purpose.

Type Collection of Timber Specimens and Commercial Exhibit

A beginning was made in October, 1925, in the formation of a Type Specimen Collection of Timbers by securing authenticated woods from the closing Wembley Exhibition. At the present time the Laboratory has upwards of 900 known and labelled woods for the purpose of assisting trade inquiries. It has also the nucleus of a useful Commercial Exhibit for reference and demonstration purposes, though the expansion of this exhibit has had to be curtailed for the present, owing to the lack of appropriate space. Valuable use has, however, been made of the various exhibits at a number of the large Agricultural Shows during 1927 in bringing the resources and activity of the Laboratory before the timber-growing and the timber-using public.

Records

In order to be in a position to deal promptly with inquiries of scientific and technical character, the work of building up the system of records was begun simultaneously with that of the Type Collection of Timber Specimens by assembling and classifying the existing data dealing with timber research. It was important to get together such records as soon as possible, not only to make available for the ready use of the public the information already existing in various forms, but also to prevent waste of time or duplication of effort on the part of the Laboratory's staff. By August, 1927, the natural growth of this side of the Laboratory's work led to the formation of the separate Section of Publications and Records for the recording of relevant information and tabulation of the results of research (see page 67).

Co-operation with other Organizations

Liaison with the work of the Imperial Institute is maintained through its Advisory Committee on Timbers, on which the Laboratory is represented.

An example of the value of the contact between these two bodies may be mentioned. When advice was sought by the Admiralty from the Advisory Committee concerning special timbers for keel blocks in the Singapore Dock, the Laboratory was in a position to place the Admiralty in direct touch with the Chief Engineer of the Belfast Harbour Commission, who had been responsible for carrying out a series of comparable tests.

During the early part of the present year an Exhibition of Empire Timbers was arranged by the Imperial Institute to further the aims of its Advisory Committee in bringing to the notice of the Trade lesser-known timbers for industrial use. In this Exhibition the Forest Products Research Laboratory was represented by a comprehensive display dealing with all branches of research work in progress.

In co-operation with representatives of H.M. Forestry Commission an extensive survey was made in the endeavour to find profitable methods for the disposal of undersized oak, of which a large volume falls to be dealt with under the clearing and replanting scheme in the Forest of Dean, Gloucestershire. A report on constructive lines was drawn up, and the suggestions contained therein are gradually being put into effect with satisfactory results, in that expansion of existing industries is taking place with greater absorption of timber.

To assist the Empire Marketing Board in the issue of a pamphlet for distribution to the schools and to the public, a note was prepared dealing with the main British Empire export timbers, covering India, Malay peninsula, and Borneo, Australia, New Zealand, South, East and West Africa, British Guiana, British Honduras, West Indies and Canada.

Co-operation with the High Commissioner for Australia has been carried out in several matters, particularly those affecting the Australian Transportation Commission. Information has been supplied on the production of charcoal, the carbonization of Australian timbers, briquetting, binders of various kinds and other relative matters. Liaison has also been established in matters affecting the general use of Australian timbers, and their substitution where suitable, for those of foreign origin.

Contact with the Trade and Industry

Visits made by officers of the Laboratory during the course of inquiries relative to the loss of timber from insect attack led to the discovery of other difficulties encountered, of which the following are examples :—

In the storage of timber in a large dock area complaints were being made concerning deterioration of certain valuable timbers, the cause of which was obscure. An examination indicated the trouble to be due to lack of attention to seasoning principles.

A firm experienced loss in the preparation of flooring timbers and it was found that case-hardening was the cause. The result was not only a suggested remedy at the time in the treatment of the timber, but later a visit from the mill manager for a brief training in seasoning, as well as continued intercourse between this concern and the Laboratory on many matters of general interest.

The competition by importing mining timber had seriously affected the trade of a Scottish business in home-grown larch. Authoritative strength figures were supplied, which indicated that home-grown larch was superior to the imported timbers. Cases such as these serve to emphasise the great value of personal touch with trade concerns

One of the Steel Companies engaged in the manufacture of saws of all kinds experienced difficulty in obtaining suitable timber of home-grown varieties for the manufacture of handles, and also had trouble in the treatment of the timber. Additional sources of securing home-grown timbers were indicated, as well as suggested methods of improvement in handling from a seasoning standpoint.

Mine Timber

To determine the suitability of home-grown pitprops and pitwood for use in the mines when prepared in the same way as those imported, a series of service trials has been carried out in the South Wales coal mines with timber of several species (Scots pine, Douglas fir, larch, Corsican pine and oak) grown on Forestry Commission areas. So far, the results from observations extending over almost twelve months have on the whole been very gratifying and distinctly encourage the use of home-grown species when these are available at competitive prices.

A survey is being carried out to collect information as to the condition, in so far as seasoning is concerned, of the timber actually used in the mines throughout Great Britain. Samples are obtained, and from these the moisture content is determined, which in turn acts as a guide to the length of time for which seasoning of the future supplies of home-grown timber will be generally necessary.

Timber Specifications

Several requests have been received for assistance in reviewing or amending out-of-date specifications, and in dealing with these care has been taken to include many British Empire woods considered suitable for the particular purposes intended, and of which there seemed to be reasonable assurance of supplies. For work of this nature very considerable time and attention are required, as well as consultation with various timber trade representatives to prevent, if possible, any hardship or undue disturbance of established methods.

Utilization of Waste

A frequent inquiry concerns the ever-present problem of waste from the sawmill and wood-working industries. A summary which was prepared some time ago of the various main uses for crude sawdust and planing mill shavings is usually supplied. It must be borne in mind, however, that each problem generally requires individual study and treatment.

Charcoal Experimental Work.

In view of the possibility that useful information would be gained for the more profitable utilization of branches and undersized timber in felling areas, of wood refuse and off-cuts from wood-working factories and similar waste material at present of value mainly as firewood, a visit was made to the Colonial Fair held at Bordeaux in 1926, where an exhibition of charcoal-making and using appliances was held, followed by a demonstration of vehicles using the gas produced from charcoal, charcoal briquettes and ordinary wood in small pieces. There appeared to be little doubt that it was practicable to manufacture charcoal in portable kilns, close to the locality of the material to be used, and that provided two men at least could be profitably employed, it was more economical to use portable kilns than the ordinary charcoal-makers' pit in the forest. Less lengthy experience appeared to be required of the operators and less attention to the kilns through the night.

Portable kilns of the French design were obtained in 1927 for experimental purposes, and later a retort of British manufacture was secured on loan. Exhaustive experiments have been made to lessen the work required in making charcoal by the ordinary method, to simplify the process, and, if possible, to increase the yield and quality. It is hoped that a development arising from this experimental work will be the design of a kiln more suitable to the vagaries of the British and tropical climates, more certain in result, more portable in the Dominions and Colonies where transport may be difficult, and less arduous to the operators in the forest.

With the assistance of the Department's Fuel Research Station, an investigation of the temperature zones in these kilns has been carried out by means of thermo-couples, to ascertain the behaviour of the various kilns and thus assist in arriving at the best type for general use.

Other aspects of the investigation deal with the value of charcoal from different species for use in motor gazogenes (or gas producers), the gradual development of the apparatus suitable for motor vehicles by British engineering firms, and controlled tests on a commercial scale with lorries or motors fitted with gazogenes. In this also it is hoped later to have the co-operation of the Fuel Research Station.

With a view to taking the tests a stage further, briquetting experiments have also been carried out, with a number of binders, since charcoal in this form has distinct advantages in certain directions, for example, in concentration of fuel value and reduction in bulk. The tests were made at the Leeds Briquette Works, Kirkstall, owned and operated by Messrs. Yeadon, Son & Co., Colliery Engineers and Contractors, Leeds, upon nine different combinations of charcoal and binders of various kinds.

Some of the resulting material has been tested for relative strength, while the remainder is held for fuel value tests in gazogenes or otherwise.

The difficulty in the disposal of waste timber products in this way is not so much in carbonization, but in finding a ready sale for large quantities of charcoal. The fact that large quantities are imported annually to Great Britain offers encouragement in this direction. Also, there is the possible use of charcoal for the manufacture of producer-gas in connexion with motor vehicles.

Miscellaneous Inquiries

A few instances have already been quoted to indicate the varied character of the inquiries dealt with. Others have been mentioned incidentally in the course of the descriptions of the work of the different Sections of the Laboratory. It may be of interest to cite some further examples.

The Laboratory was approached by the Federated Home-Grown Timber Merchants' Association on behalf of one of its members—a large concern in Lincoln—to find uses for planing mill wastes, shavings, and so on. Investigations are proceeding as to whether the waste might be used—after grinding—in place of the wood flour now imported from Germany and Scandinavia. Specimens prepared by the Laboratory in its wood chemistry department have been submitted to linoleum manufacturers for trial purposes, and the reports are hopeful. The results to date have been communicated to the inquirers.

A London firm asked for assistance in finding suitable timbers for the manufacture of boot lasts. Various Empire and home-grown timbers were suggested, of which possibly either home-grown or Canadian birch may be found suitable.

It was found that a Glasgow firm were obliged to import chestnut fence pales from France, and they were placed in touch with the Forestry Commission regarding the development of chestnut areas in Gloucestershire, where steamer shipment appeared to be a possibility.

Information has also been supplied to a large timber-importing firm on the relative value of certain Empire timbers with a view to substitution for American pitch pine as steamer decking.

Frequent requests are received for authenticated commercial specimens of timbers, particularly of Empire origin, and also for specimens for general information. For instance, steps have been initiated, in co-operation with H.M. Office of Works, for examining the value of home-grown beech as a flooring timber. Again, if some form of collective supply can be made available, home-grown beech may be able to compete successfully with imported Continental beech now used in very large quantities for furniture manufacture.

A mining concern experiencing trouble with pitch pine cage-guides asked for a specification to ensure the supply of the correct class of timber. While full information was given as a matter of general assistance, attention was drawn to the Empire woods from Canada and Australia suitable for the purpose. The names of suppliers and prices were also given ; incidentally, these prices were less than for the American timber previously used.

A preliminary inquiry has been made in collaboration with H.M. Office of Works into the steps which can be taken to substitute an Empire-made product for the American and Scandinavian doors now reaching the British market in such large quantities.

The Laboratory was approached by a firm concerning timber for drum shells, usually made from wide ash (now becoming scarce) or, more recently from American magnolia Tasmanian myrtle was suggested to them, and an order has been placed for some logs of this timber for the purpose of trial.

Grading specifications were prepared concerning timber for use in the manufacture of ladders for a London company. This dealt with a number of Canadian timbers to take the place of Scandinavian ones for certain types of ladders. After a period it has been found that the Canadian timbers so described are now extensively used by the company in the manufacture of their products.

An indication of the assistance which may be given by the Laboratory to the Dominions is afforded by the request from the Agent-General, British Columbia, for technical information relative to Canadian Douglas fir, with a view to its possible use instead of American pitch pine in the Port of London Dock extension work. Following a careful examination of the subject from the engineering standpoint, including inspection of works in Belfast Harbour, a report was prepared and forwarded, embodying also a note on the strength factors and similar qualities. The Agent-General was successful in having at least half a million cubic feet of the Canadian timber specified and used.

Training Forest Officers in Utilization

The first (South Nigerian) Forest Officer to undergo training in Utilization work at the Laboratory has recently completed a six months' course, and, in addition to being made familiar with routine experimental work, he has also been required to give attention to commercial procedure, affecting importation, handling, storage, selling and the general movement of timber into the hands of the actual consumer. A South African Forest Officer has now reported for a six months' course of instruction.

Publications and Records

Apart from the detailed records kept by individual Sections concerning special subjects, a systematic collection is made of information and records permanently required,

or likely to be so required, not only in connexion with the research work of the Laboratory, but also in answering inquiries from the trade. A library of indispensable works of reference is also being assembled. Periodicals bearing on timber research and allied subjects are regularly perused and circulated to the members of the staff, pertinent articles being card-indexed and classified so as to be readily available to inquirers. At present the Library contains, roughly, 1,500 books, journals, etc., and the number of periodicals received or in circulation is, approximately, 60.

The Section also assists in the preparation of the Laboratory reports for press. So far, the publications issued through H.M. Stationery Office have comprised two Special Reports, two Bulletins, two Technical Papers, two under Projects and one under Miscellaneous. In addition, contributions have been made to the *Biochemical Journal*, the *Annals of Applied Biology*, *Forestry* and to the trade and general press. A full list of the papers published, or in preparation for publication, is given in Appendix II.

RALPH S. PEARSON,
Director.

October, 1928

APPENDIX I

LIST OF SCIENTIFIC AND TECHNICAL STAFF

(*30th September*, 1928)

Director of Forest Products Research : R. S. Pearson, C.I.E., F.L.S.

Assistant Director : F. M. Oliphant.

Scientific Field Assistant : A. N. David.

Records Officer : W. H. Lovegrove.

Technical Assistant (Photographer) : W. R. Hutchins.

Section of Seasoning

Officer in Charge : S. T. C. Stillwell, B.Sc.

Junior Assistants : R. G. Bateson, B.A. ; R. A. G. Knight, B.Sc. (Eng.) ; W. C. Stevens, M.A.

Junior Technical Assistants : L. S. Doman ; R. E. Hodge ; D. D. Johnston ; R. J. Newall.

Section of Timber Mechanics

Officer in Charge : C. J. Chaplin, M.Sc., M.E.I.C.

Assistant, First Class : F. M. Mooney, B.Sc., A.M.E.I.C.

Junior Assistants : F. H. Armstrong, M.Sc. · T. Hamilton, B.Sc. ; J. Latham, B.Sc. ; R. K. Mawson, B.Sc. ; E. H. Nevard, B.Sc.

Technical Assistant : Miss A. Hart, B.Sc.

Junior Technical Assistant : C. F. Ellis.

Temporary Assistants : Miss N. L. Forster, B.Sc. ; Miss I. M. Elliot, B.Sc.

Section of Utilization

Officer in Charge : J. R. Cosgrove, D.S.O., M.C., M.E.I.C.

Junior Assistant : J. A. Buchanan, B.A.

Technical Assistant : J. C. Thirlwell.

Section of Wood Preservation

Officer in Charge : J. Bryan, M.Eng., A.M.Inst.C.E.

Section of Entomology

Officer in Charge : R. C. Fisher, Ph.D., B.Sc.

Junior Assistant : F. R. Cann, D.I.C.

Section of Mycology

Officer in Charge : K. St. G. Cartwright, B.Sc.

Junior Assistant : W. P. K. Findlay, B.Sc., A.R.C.S.

Oxford Branch

Officer in Charge : J. F. Martley, M.Sc., D.I.C., A.R.C.S.

Junior Assistants : (Section of Wood Technology), S. H. Clarke, B.Sc.; J. C. Maby, B.Sc., A.R.C.S., F.R.A.S. ; B. J. Rendle, B.Sc. ; E. D. van Rest, B.Sc. (Section of Wood Chemistry), W. G. Campbell, B.Sc. ; J. Booth, B.Sc.

Investigator (at St. Andrew's University) *:* Miss M. H. O'Dwyer, Ph.D.

APPENDIX II

LIST OF PUBLICATIONS ISSUED OR IN PREPARATION

A.—*Stationery Office Publications**

TECHNICAL PAPERS :—

s. d.

No. 1.—Movement of Moisture with reference to Timber Seasoning. By S. T. C Stillwell, B.Sc. .. .. (1926) 1 6

No. 2.—Moisture Movement through Wood—The Steady State. By J. F. Martley, D.I.C., B.Sc. ... . (1926) 1 3

SPECIAL REPORTS :—

No. 1.—The Air-seasoning and Conditioning of Timber. By F. M. Oliphant (1927) 2 0

No. 2.—The Principles of Kiln-seasoning of Timber. Part I. Types of Commercial Kilns in Use. By S. T. C. Stillwell, B.Sc. .. .. (1928) 0 9

BULLETINS :—

No. 1.—Dry Rot in Wood .. .. (1928) 1 6

No. 2.—*Lyctus* Powder-Post Beetles. By Ronald C. Fisher, B.Sc., Ph.D. .. (1929) 3 0

PROJECTS :—

No. 1.—Mechanical and Physical Properties of Timber—Tests of Small Clear Specimens. By C. J. Chaplin, M.Sc., M.E.I.C. .. .. (1928) 2 0

No. 1—Progress Report No. 1. Tests of Some Home-Grown Timbers in their Green Condition. By C. J. Chaplin, M.Sc., M.E.I.C. .. .. (1928) 0 9

MISCELLANEOUS :—

The Uses of Home-Grown Timber. *Compiled by a Committee comprising representatives of The Land Agents' Society, The Federated Home-Grown Timber Merchants' Association, The Royal Institute of British Architects and the Forest Products Research Laboratory* .. .. (1928) 1 0

B.—*Other Publications*

CHAPLIN, C. J.

Application of Timber Testing. *British Association.* 1926.

CLARKE, S. H.

On the Relationship between Vessel Size and Liability to attack by *Lyctus*. *Forestry,* 1928, **2**.

FISHER, R. C.

Timbers and their Condition in relation to *Lyctus* attack. *Forestry,* 1928, **2**, 40.
The relation of the elm bark beetles to their host trees. *Forestry,* 1928, **2**, 53.

MABY, J. C.

Report on Wood Fragments from the remains of a Lake Settlement at Neuchatel. *Antiquity.* (*In the press.*)

MARTLEY, J. F.

Moisture Movement in Wood. I.—The Transfer of Moisture between two Discs of Wood. *Ann. Applied Biol.,* 1926, **13**, 37–54.
Comparison between Kauri Pine and Swamp Kauri. (*Agathis Australis.*) *Ann. Applied Biol.,* 1927, **14**, 4.
The Activities of the Oxford Branch Forest Products Research Laboratory. *Ann. Applied Biol.* (*In the press.*)
Research on Wood Structure. *Forestry,* 1928, **2**.
Theoretical Calculation of the Pressure Distribution on the Basal Section of a Tree. *Forestry,* 1928, **2**.

* To be obtained from the addresses given on back of wrapper.

NUTMAN, F. J.

Studies with Wood Destroying Fungi. I.—*Polyporus hispidus* (Fries). *Ann. Applied Biol.* (*In preparation for the press.*)

O'DWYER, Miss M. H.

The Hemicelluloses of Amerian White Oak. *Biochem. J.*, 1923, **17** (4), 501–509.
A Note on the Occurrence of a Pectic substance in Beech Wood. The Hemicelluloses. Part IV. *Biochem. J.*, 1925, **19** (5).
The Hemicelluloses of Beech Wood. *Biochem. J.*, 1926, **20** (6).
Preliminary Investigations on the Constitution of the Hemicelluloses of Timber. *Biochem. J.*, 1928, **22** (7), 381–390.

OLIPHANT, F. M.

Forest Products Research in Great Britain. *Forestry*, 1927, **1**.

PEARSON, R. S.

Hardwoods. *Forestry*, 1928, **2** (1), 10.

STILLWELL, S. T. C.

The Seasoning of Timber. *British Association.* 1926.

Printed under the authority of HIS MAJESTY'S STATIONERY OFFICE
By Harrison and Sons, Ltd., 44–47, St. Martin's Lane, W.C.2.

(B 12/739)Q Wt. 20591–1665 1000 6/29 H & S Ltd. Gp. 12